Space, Air, Sea, Land, Urban

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Global Security

Professor Chris Chatwin,

Dr Young, Dr Birch – IET – Hawth,

Crawley – 6th March 2012

Global Security - Summary

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- Space Surveillance Network (SSN) & GPS
- Updating the Space Surveillance Network

Updating the Space Surveillance Network

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- Space Based Space Surveillance (SBSS) LEO
- Space Based Infrared Systems (SBIRS) GEO & LEO
- Defence Meteorological Satellite Program (DMSP)
- Wideband Global SATCOM (WGS)
- Some Data Collection Systems
- Global Fibre Network
- Data Centres
- Space, Air, Sea, Land, Urban

Satellite Frequency Bands Chart

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Letter designation for satellite frequency band	Frequency Range (GHz)
L	1-2
S	2-4
C	4-8
X	8 - 12 (8 - 12.5 in North America)
Ku	12 - 18 (12.5 - 18 in North America)
K	18 - 27 (18 - 25.5 in North America)
Ka	27 - 40 (26.5 - 40 in North America)
O	40 - 50
V	50 - 75

Ground-*Based* Electro-Optical Deep *Space* Surveillance Cluster

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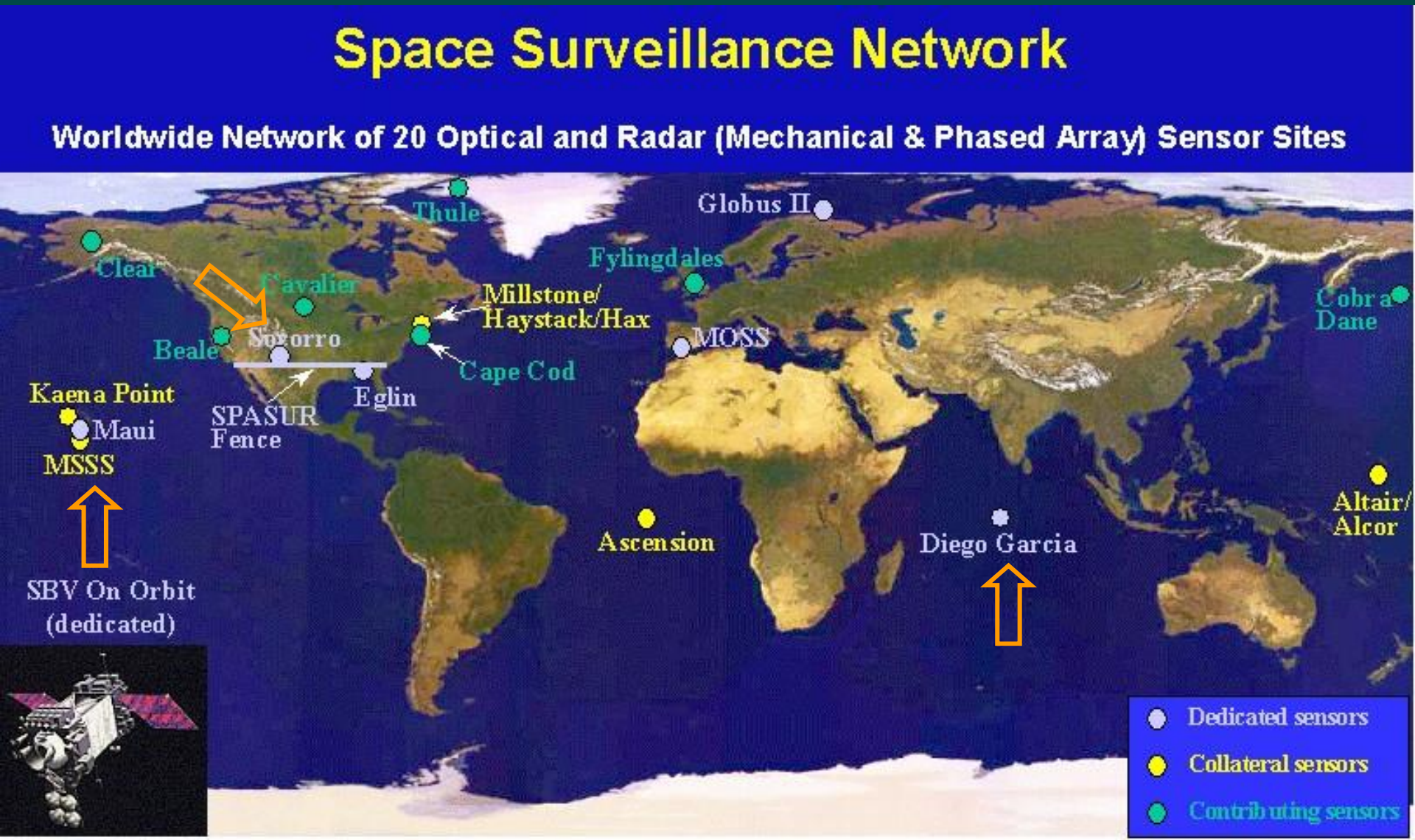

Space Based Visible surveillance (SBV) - LEO Legacy system

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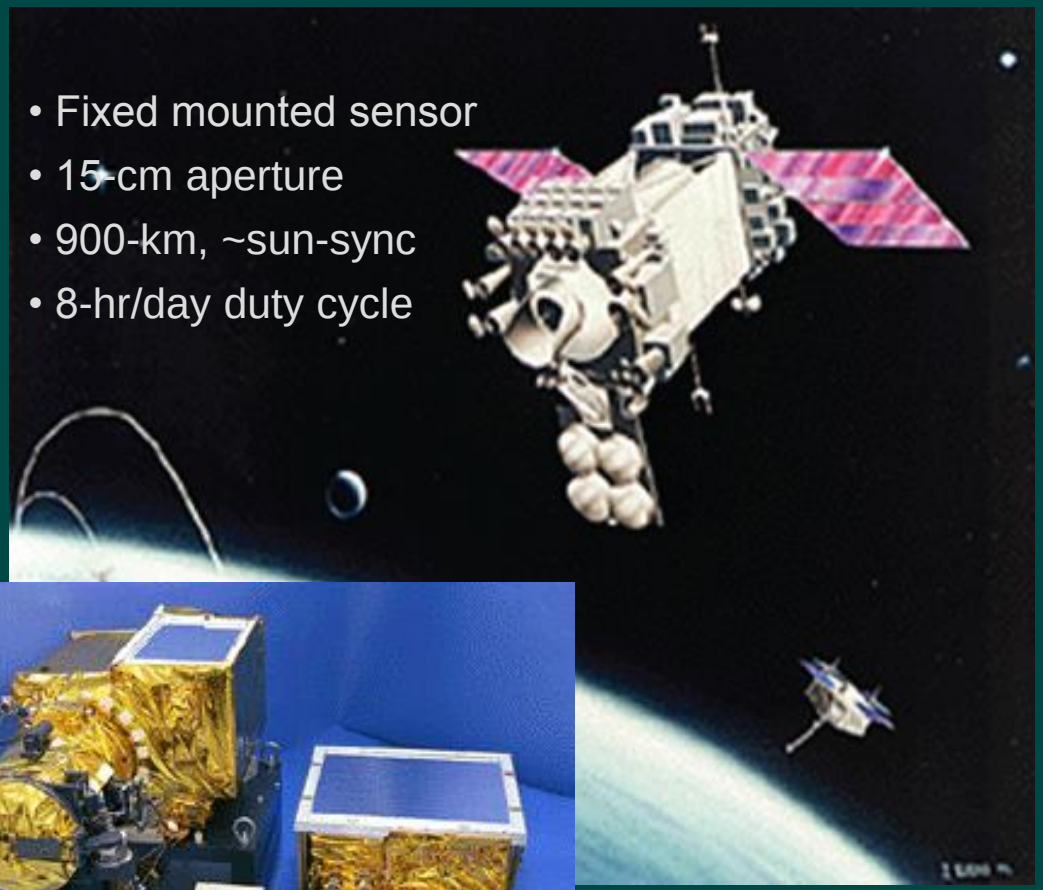

MSX Mid-Course Space Experiment

MSX/SBV

- Primary Mission – Space Surveillance
- Conduct space surveillance from space
- Surveillance of entire geosynchronous belt
- Assured access to objects of military interest

Global Data Integration Technology

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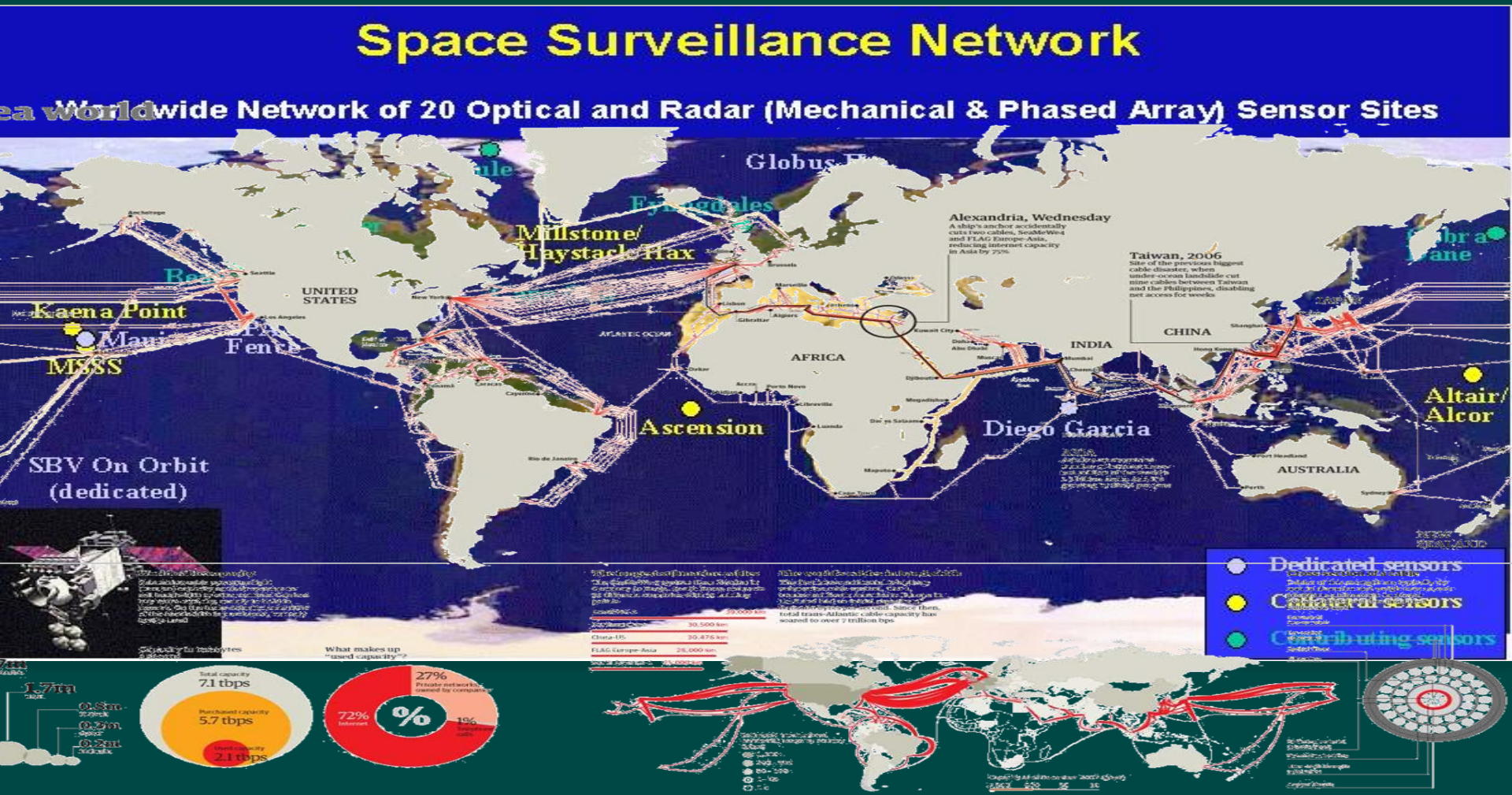

Military Satellite Communication Systems Integrate into the Global Fibre Backbone

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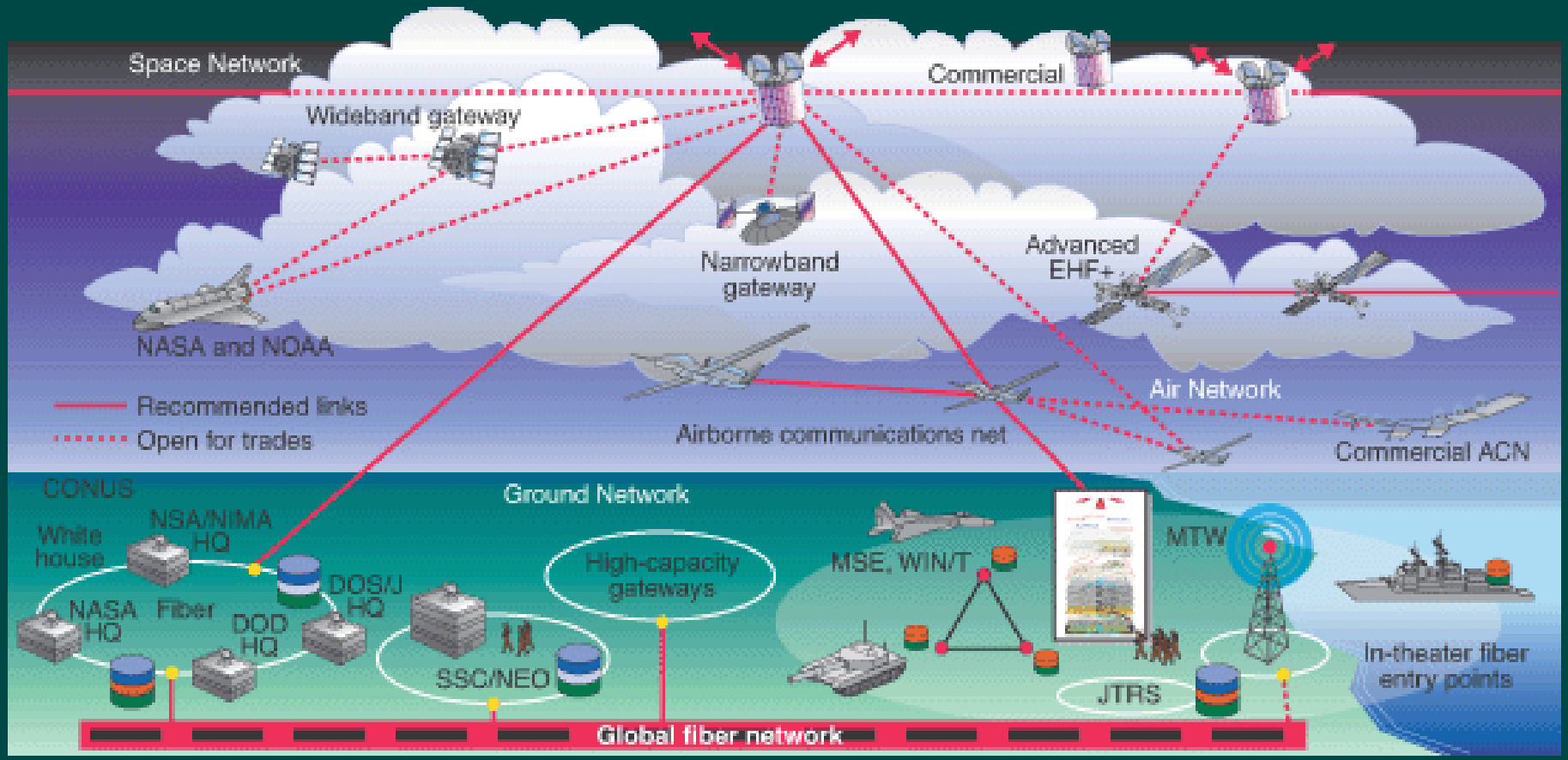

Ground-*Based* Electro-Optical Deep *Space* Surveillance (GEODSS) - Diego Garcia / Maui / Socorro

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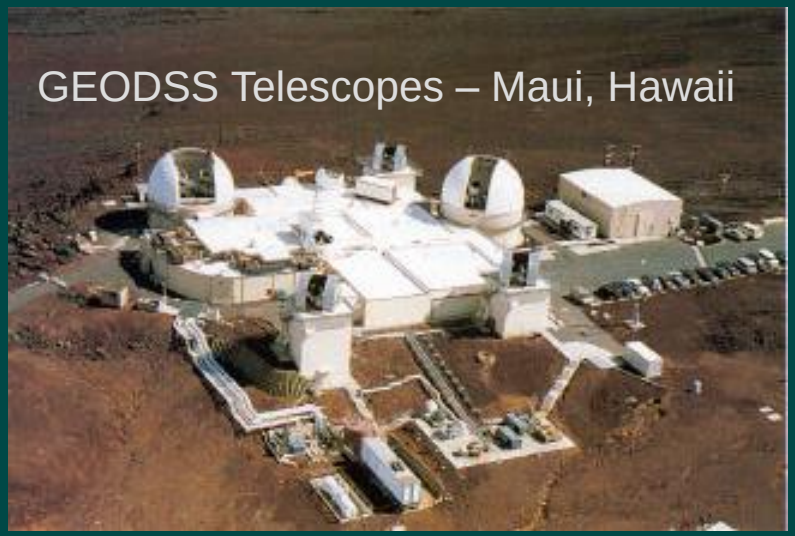
- **Primary Mission: Space Surveillance**
- **Supports Air Force Space Command (AFSPC) as a dedicated Deep Space (DS) sensor**
- **GEODSS brings together the telescope, low-light-level cameras, SBV and computers**



Inside Diego Garcia GEODSS Station

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Monitoring Space Objects

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B53 Nuclear Bomb (9 Mt TNT)

Space Surveillance

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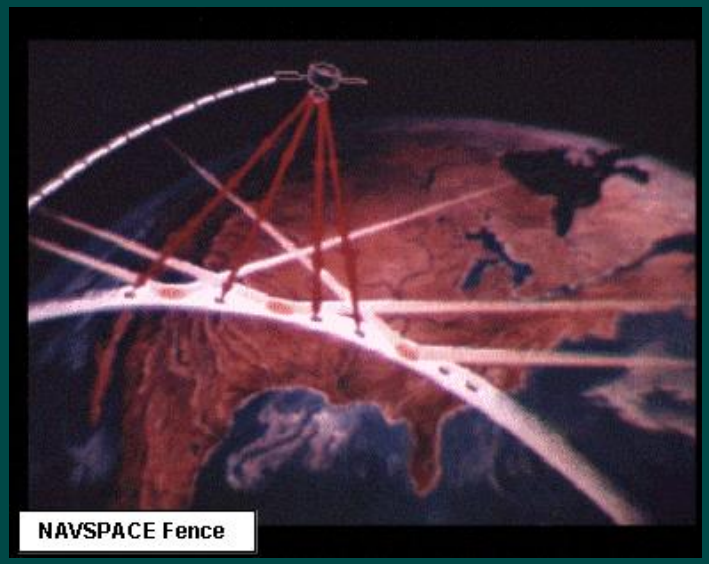
- Conduct space surveillance from space
- Surveillance of entire geosynchronous belt
- Assured access to objects of military interest



NAVSPACE Fence

- Provides up to date satellite orbital elements to Fleet and Fleet Marine forces
- Supports US Space Command as part of nation's worldwide Space Surveillance Network

Haystack Radar for Space Surveillance

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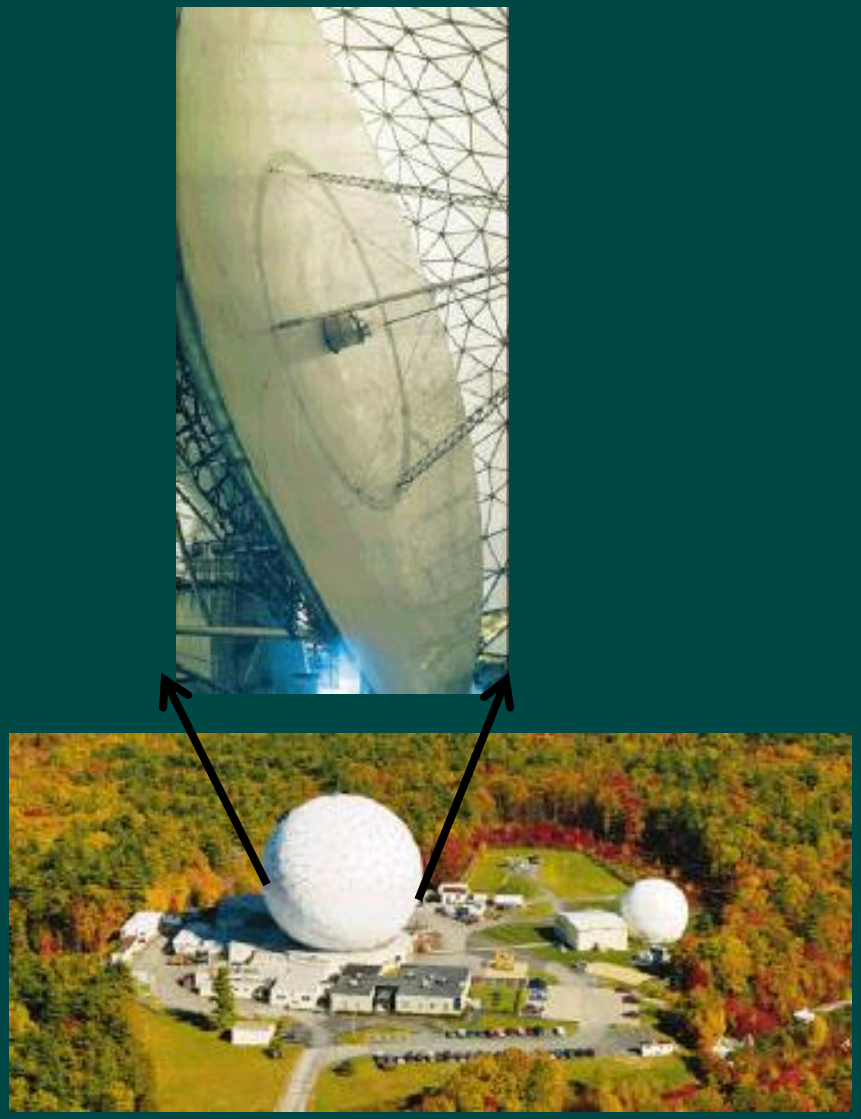

- Haystack is a mechanical tracker
- Only sensor in the SSN capable of imaging NE and DS objects
- Provides images for Mission Payload Assessment (MPA) and satellite status determination
- High resolution in NE (25 cm)
- All weather day/night capability
- Conducts measurements of space debris to sizes of 1 cm (NASA)
- NASA debris campaign
- Provides unique support for satellite anomaly resolution

Eglin Mission Phased Array Radar Dedicated to Space Surveillance

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- **Primary Mission: Spacetrack as dedicated sensor**
- **Tracks 4,257 NE and 357 DS objects per day**
- **Space Surveillance Analysis Tool (SSPAT)**

- **Covers 120 degrees in azimuth and in excess of 22,000 NM in range**
- **Has capability to track small objects**

Space Junk

What resolution is needed

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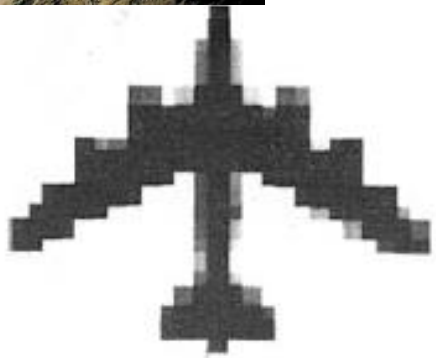
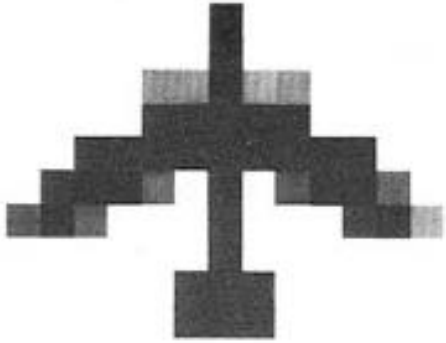
ORIGINAL

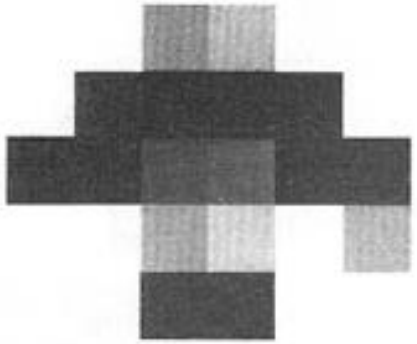
1 METRE SAMPLE



2.5 METRE SAMPLE



5.0 METRE SAMPLE



10 METRE SAMPLE

Source: B. Jasani and G. Stein, *Commercial Satellite Imagery. A Tactic in Nuclear Weapon Deterrence*, Springer, 2002

Satellite Image of Military Vehicles

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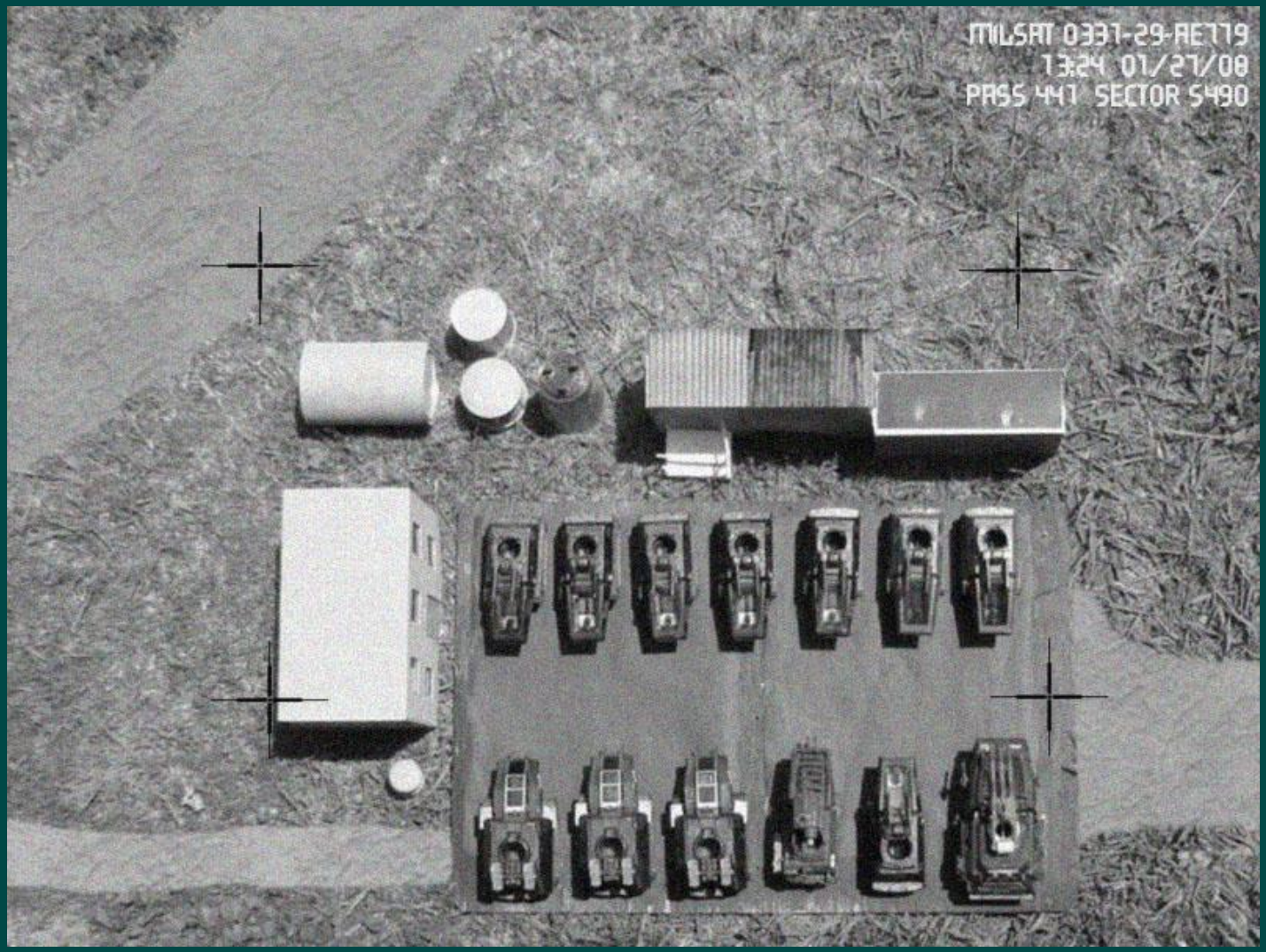

Global Positioning System

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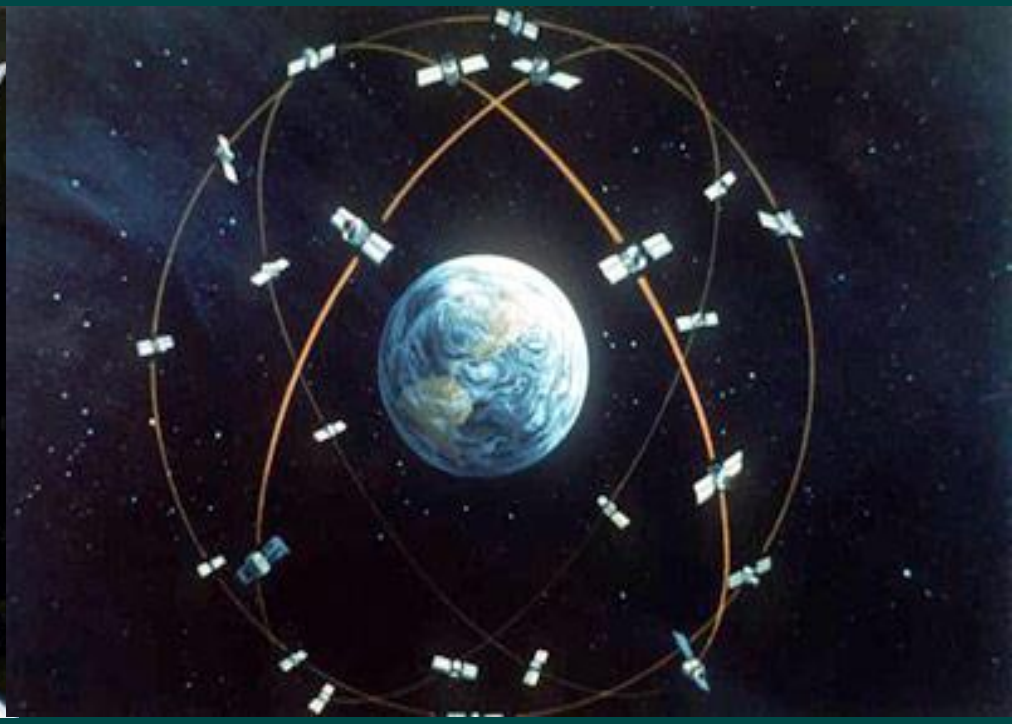
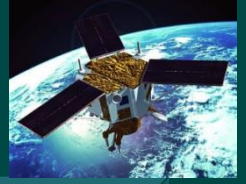


- 24 spacecraft in 12 hour circular orbits, with 3 on-orbit spares. Six circular orbital planes, R=26,560km
- All users with clear view of sky see the minimum of 4, but usually see 6-8



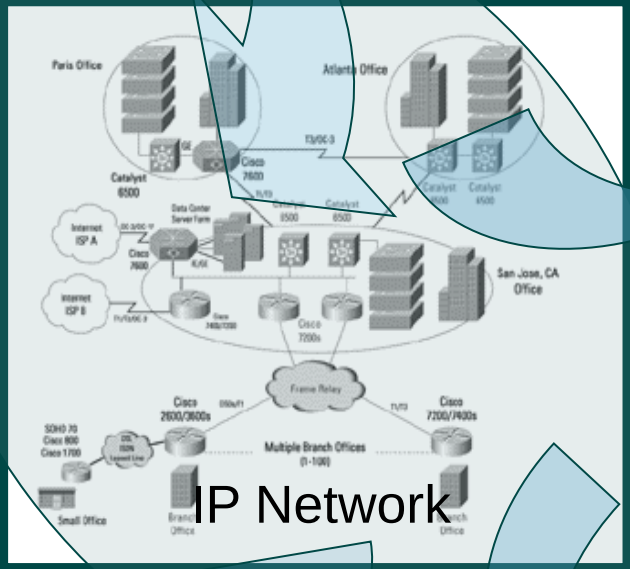


Urban Surveillance

Control Room

Alerts & Meta Data

Smart IP Cameras
mapped into 3D space



IP Network

Data & Meta-
Data Storage

Responders

Urban Surveillance - GPS and Security Cameras

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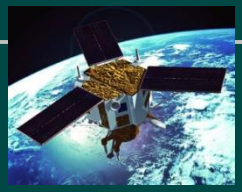

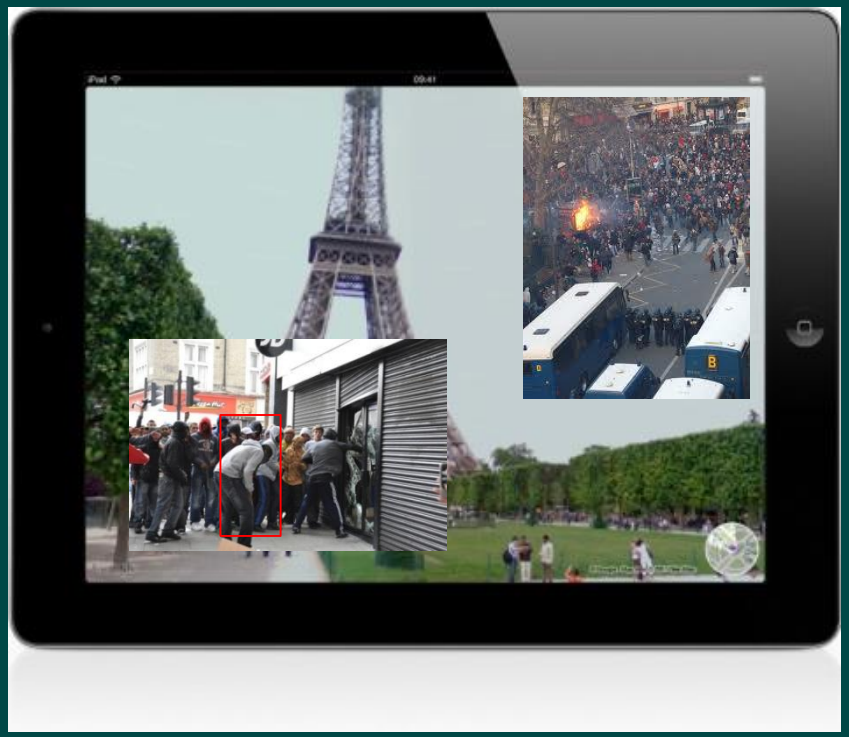

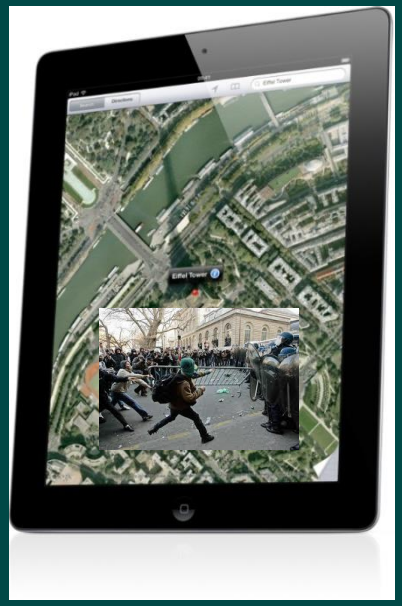

Galileo should be operation by 2014, it will be inter-operable with GPS and GLONASS

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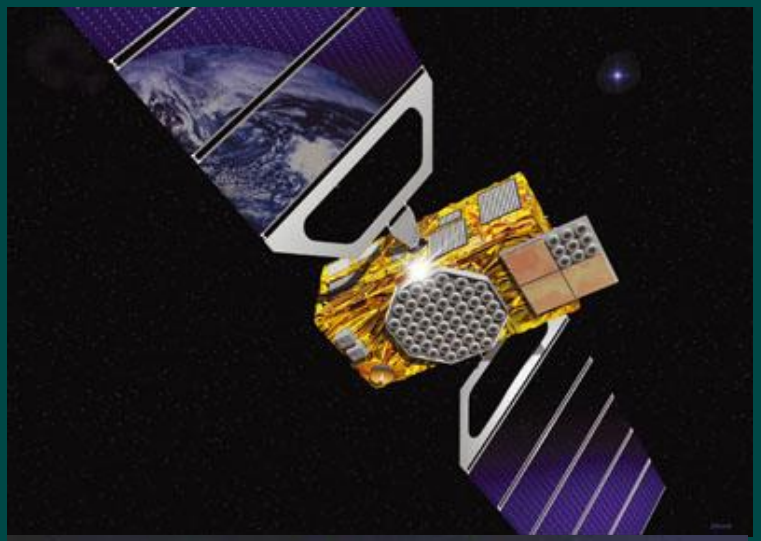

30 satellites in Medium Earth Orbit (MEO) at an altitude of 23 222 km

Ten satellites will occupy each of three orbital planes inclined at an angle of 56° to the equator.

The inclination of the orbits was chosen to ensure good coverage of polar latitudes, which are poorly served by the US GPS system.

History of Satellite Images

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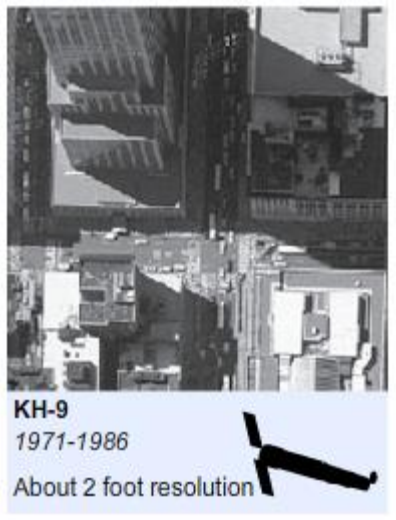
- Examples for resolution



IKONOS Stereo Satellite Imagery
Multispectral Blue, Green, Red, and NIR.

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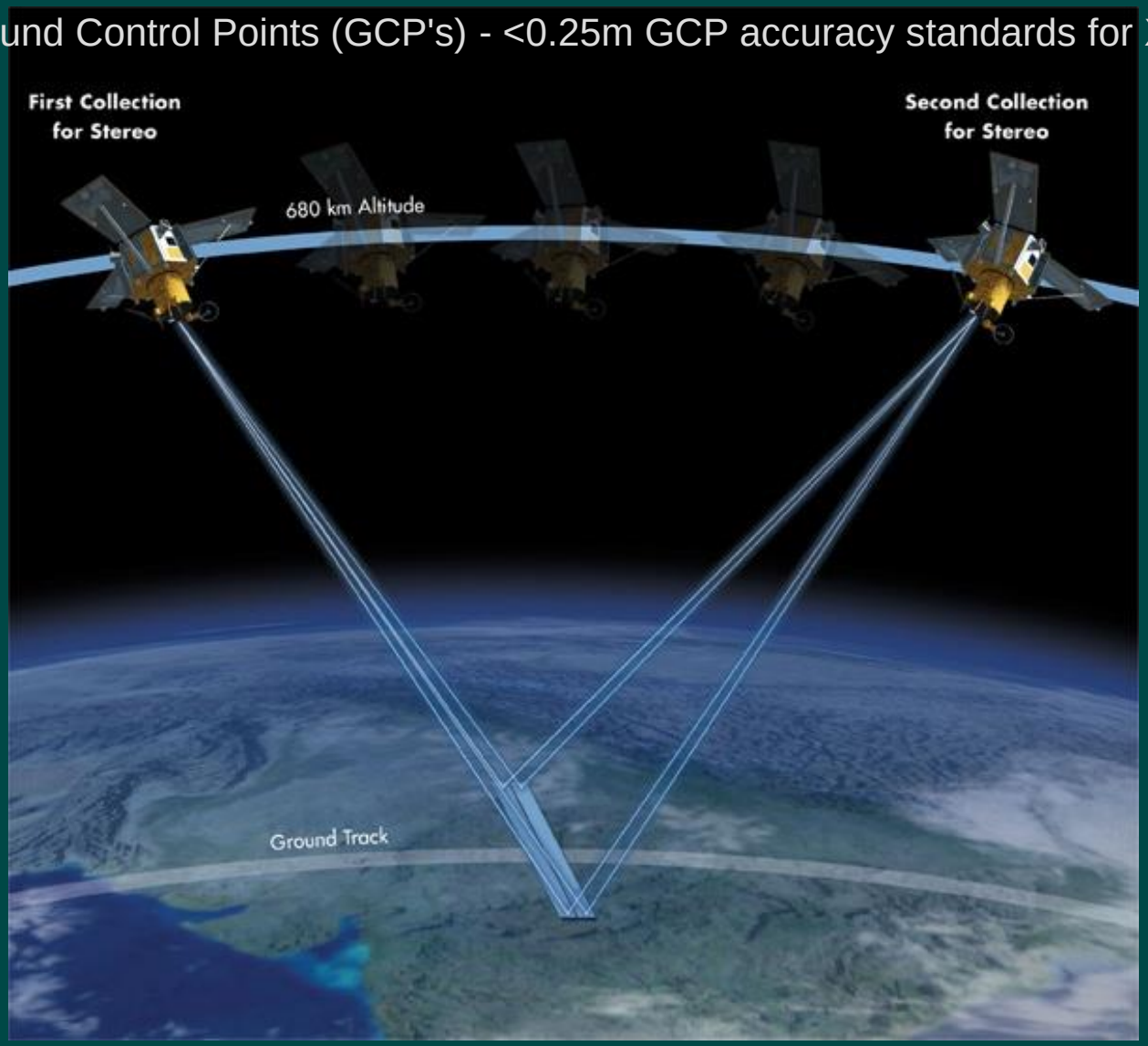
With Ground Control Points (GCP's) - <0.25m GCP accuracy standards for X, Y, Z



Quickbird, 450 km LEO, 98˚, sun-synchronous inclination, 60 cm resolution

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Multispectral:
Blue: 450 - 520 nanometers
Green: 520 - 600 nanometers
Red: 630 - 690 nanometers
Near-IR: 760 - 900 nanometers

KH-11 family of satellites

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- First launched in 1976, believed to look similar to the Hubble Space Telescope (2.4 metre telescope)
- Infrared imagery capability
- Elliptical orbit between 150 miles and 600 miles
- Resolution 10-15 centimetres
- Data transmission via SDS military relay satellites.

Space Based Space Surveillance (SBSS) Mission Statement

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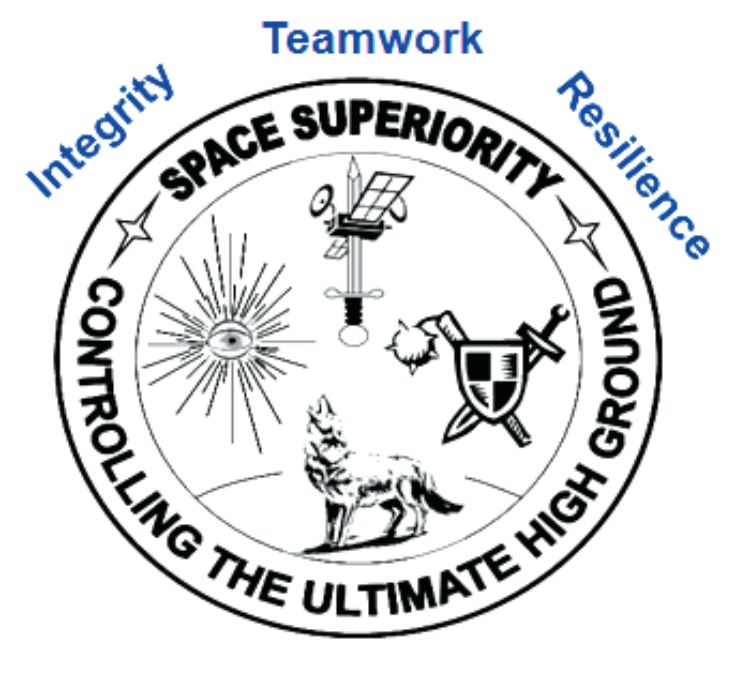

One team working together to deliver space surveillance capability that defends our nation and protects our families.

Space Based Space Surveillance (SBSS) - Operates in conjunction with the Space Surveillance Network (SSN)

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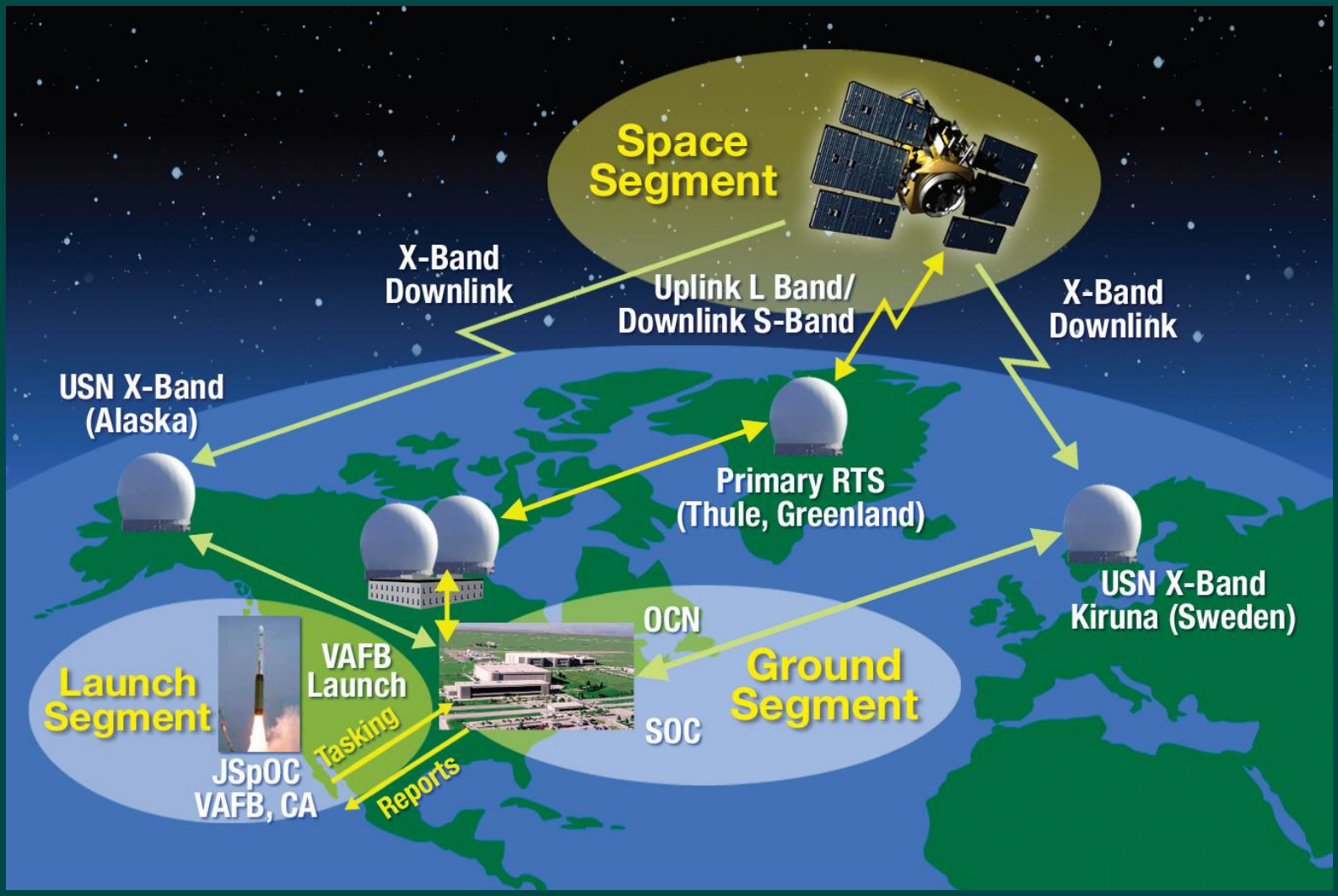

USN Universal Space Network; RTS Remote Tracking Station; VAFB Vandenberg Air Force Base;JSpOC Joint Space Operations Centre; OCN Operational Control Node; SOC Satellite Operations Center

Space Based Space Surveillance, LEO

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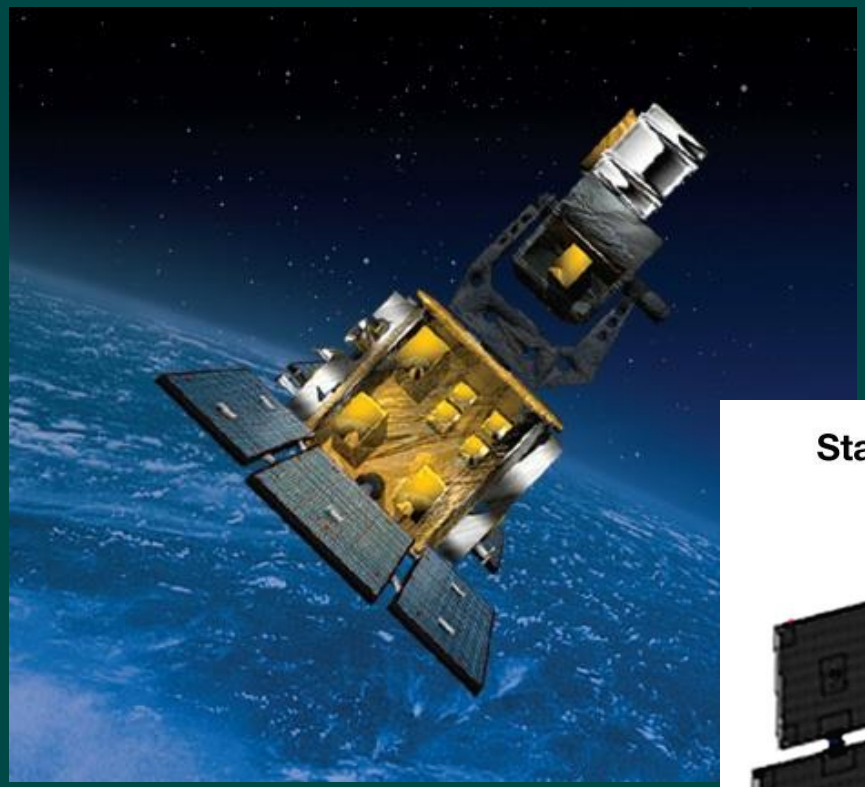
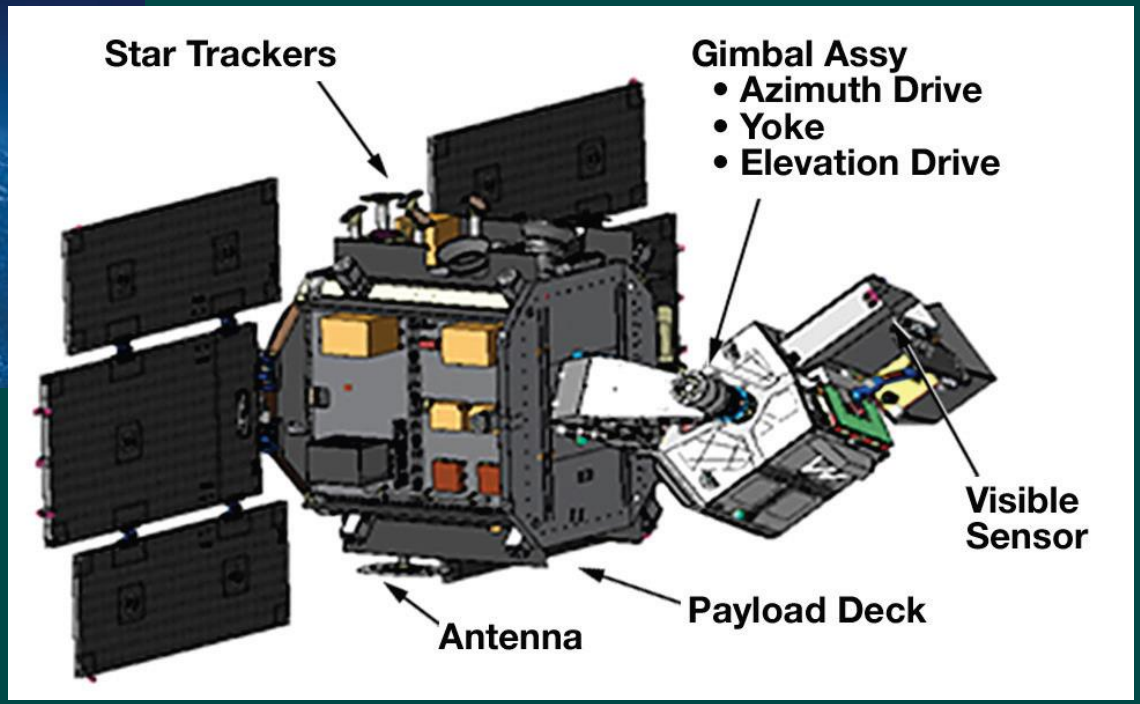


SBSS Delivers:

- 2-axis gimbaled sensor
- Large aperture
- 630-km, ~sun-sync
- 24-hr/day duty cycle



Better Timeliness

Better Sensitivity

Increased Capacity

Increased Orbit Accuracy

SBSS is free of terrestrial limitations – 24/7 on orbit data collection

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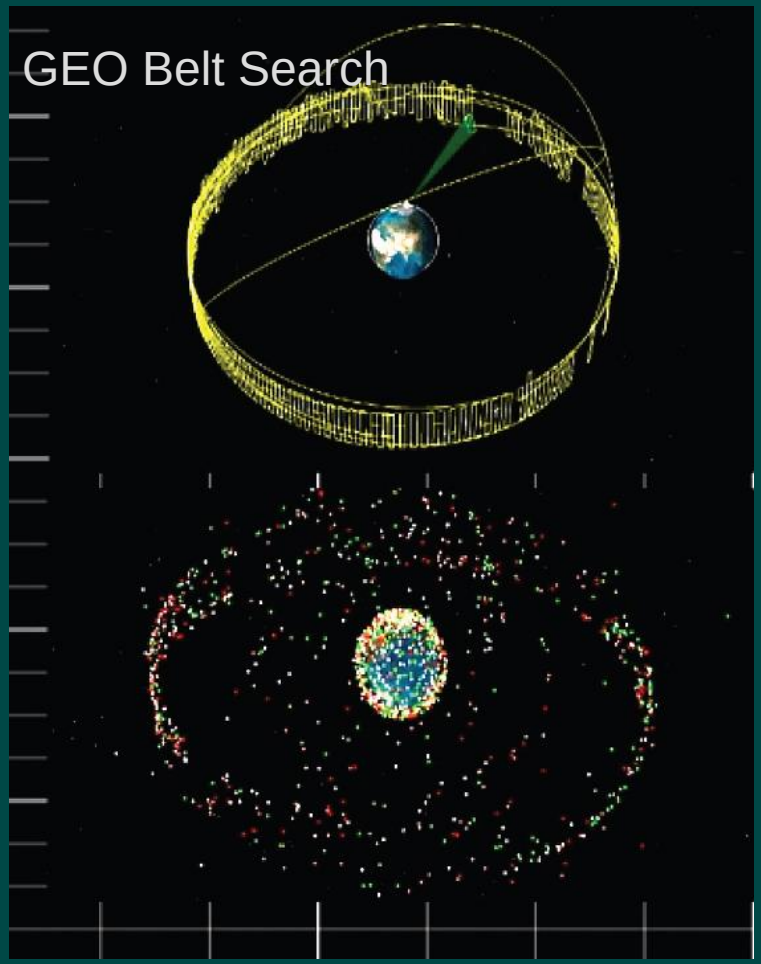
Detection of faint objects including space debris



Ball Aerospace SBSS Block 10 Space Vehicle

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- Payload processor to control all payload functions, all Line of Sight pointing and data collects.
- Highly agile, two-Axis gimbal points the visible sensor.
- Visible Sensor: This includes a three-mirror anastigmatic telescope, a focus mechanism, a filter wheel with seven selectable filters, the focal plane assembly (FPA), an on-board calibration system
- Boeing On-Board Mission Data Processor (OBMDP) performs image processing to extract moving targets and reference star pixels to reduce the downlink size.

Satellite Operations Centre (SOC)

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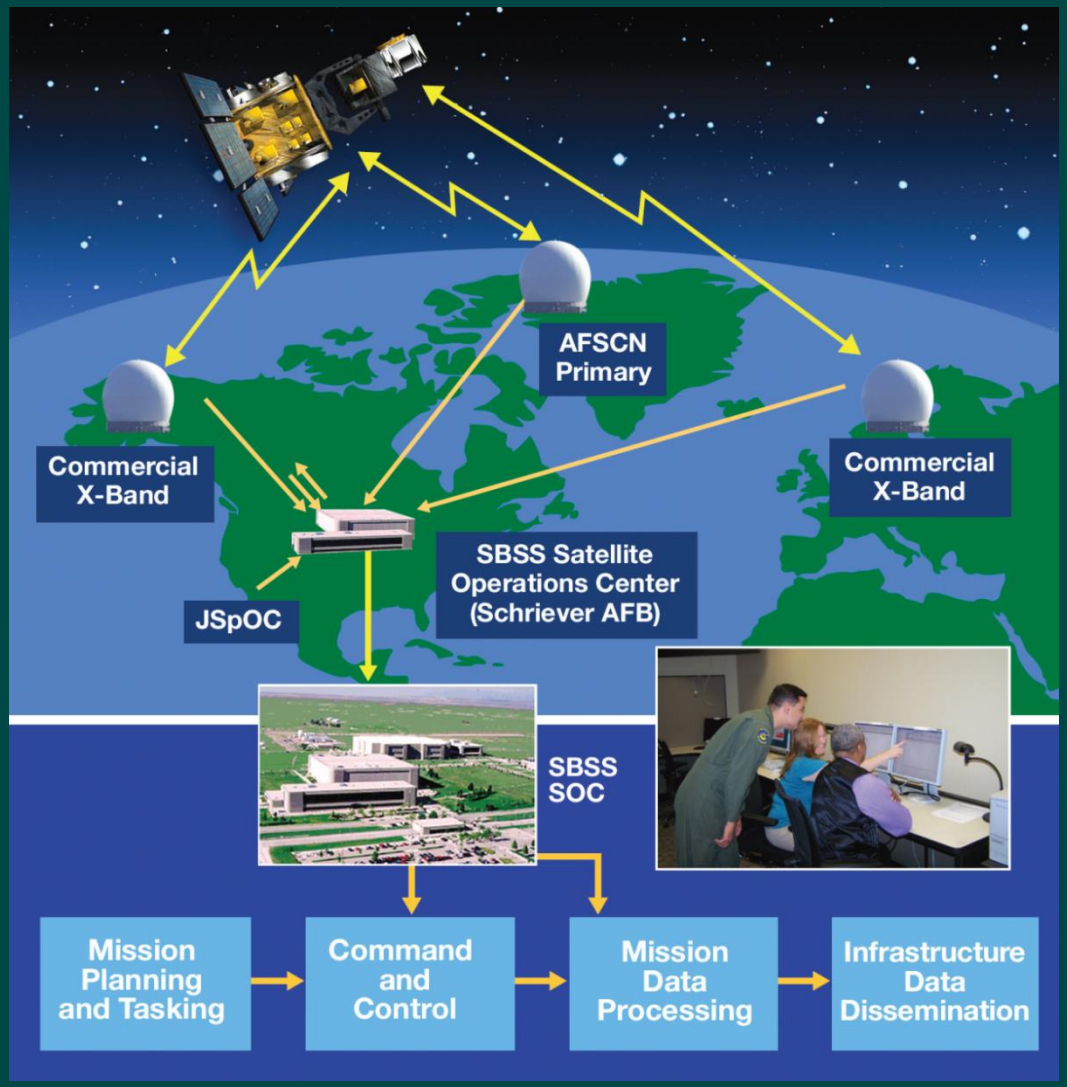

JSpOC Joint Space Operations Centre; AFSCN Air Force Satellite Control Network; AFB Air Force Base

SBSS Mission Overview

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- Find/fix/track space objects.
- Enable threat determination and defensive strategies.
- Track resident space objects (RSOs) in deep space and near Earth.
- Provide position, manoeuvre detection, and space object ID data.
- Collect metric and space object identification (SOI) data.
- Support intelligence preparation

Real Time Space Situational Awareness (SSA) - LEO 630-km, ~sun-sync

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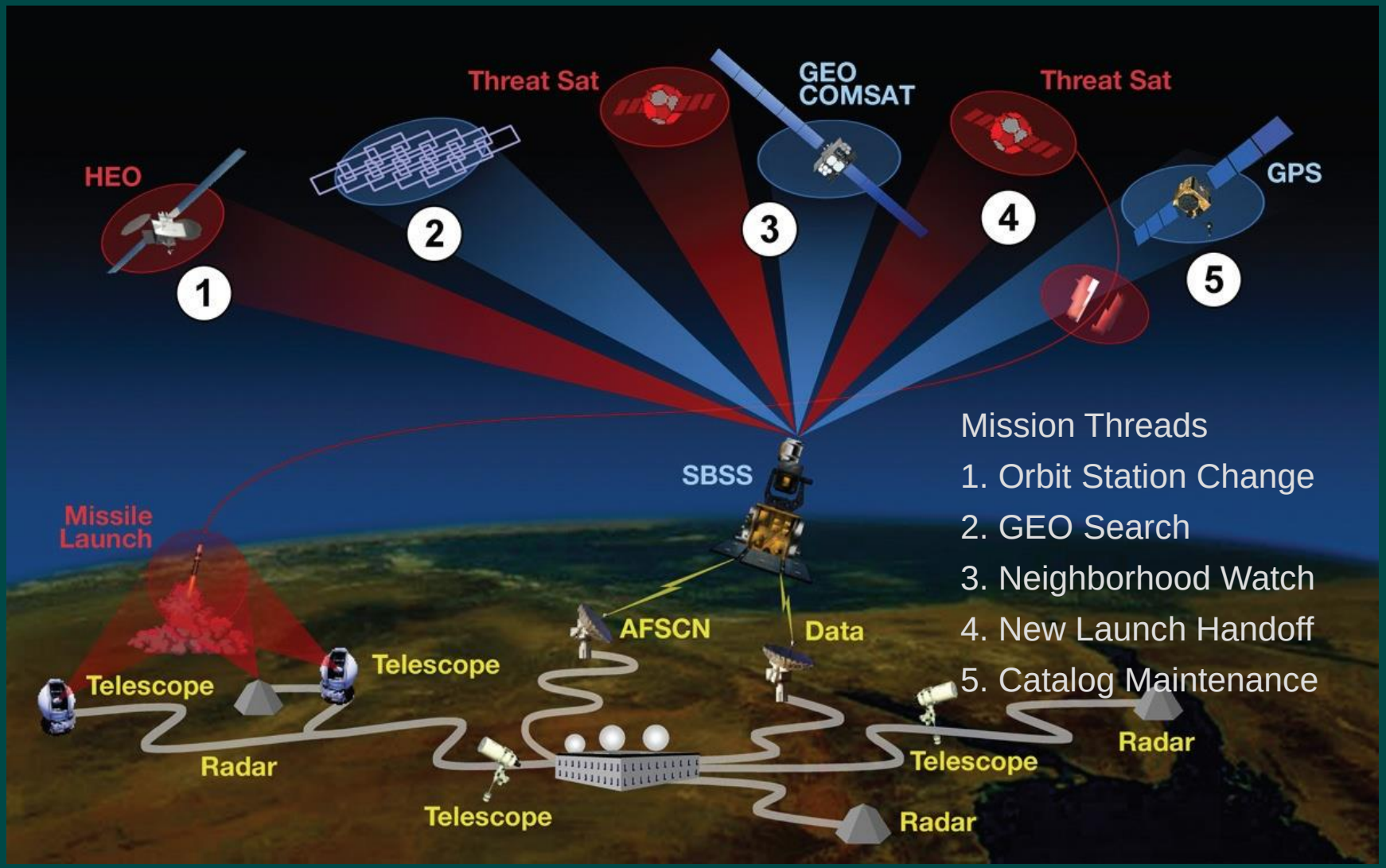

AFSCN Air Force Satellite Control Network

Space Based Infrared Systems (SBIRS), GEO

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- Global, persistent missile surveillance continues to be a critical national security space mission.

- A Cold War focus on the strategic ICBM threat has extended to include emerging threats such as short- and mid-range ballistic missiles in the hands of many nations - some openly hostile to the United States and its allies.

Space Based Infrared Systems (SBIRS) GEO

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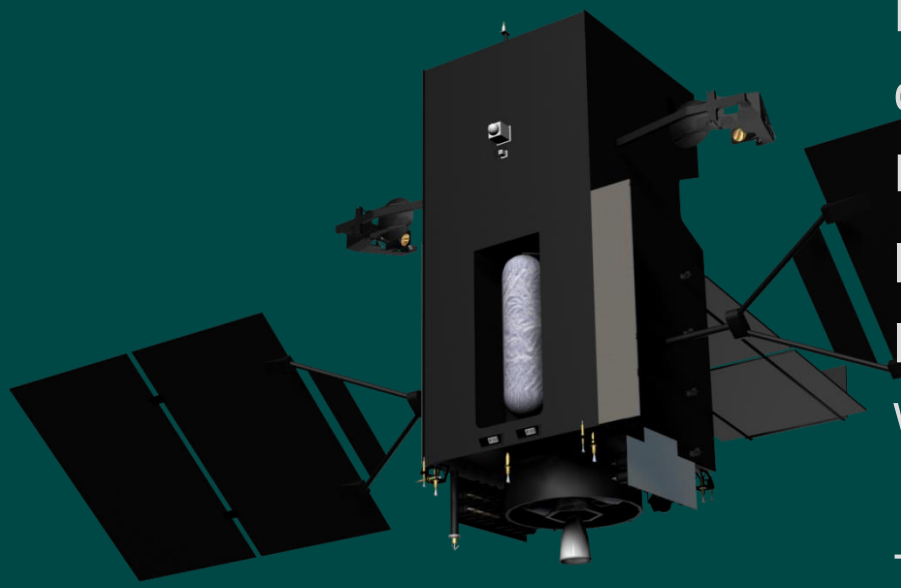

3-axis stabilized with 0.05 deg pointing accuracy

The U.S. Air Force, in partnership with Lockheed Martin is deploying Space Based Infrared Systems (SBIRS) contributes to the Department of Defence mission to deter war and protect the security of the U.S. by providing timely and accurate missile warning/defence information.

The SBIRS systems are critical for protection against global and theatre ballistic missile attacks against the U.S., its deployed forces and its allies.

Space Based Infrared Systems (SBIRS) 12 year design life

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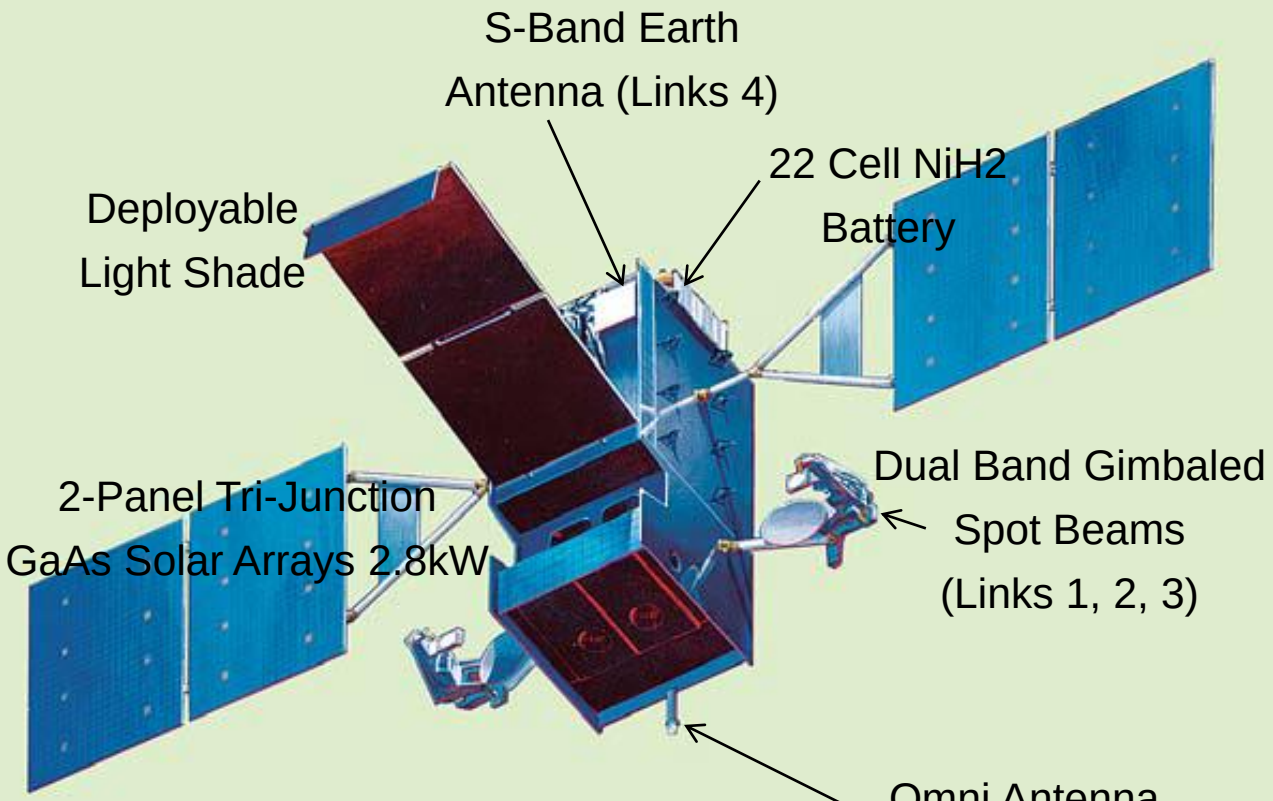

3-Color IPR Payload; Short Schmidt Telescopes with Dual Optical Pointing (Scanner and Starer)

Link Band Function

1-S down Ka Survivable mission data

1-T down Ka Normal mission data

2 up QHF Anti-jam commanding

3 down Ka Wideband sensor data

4 down S Theater mission downlink

5 down S Backup SGLS telemetry downlink

6 up S Backup SGLS commanding

Efficiency of Solar Cells

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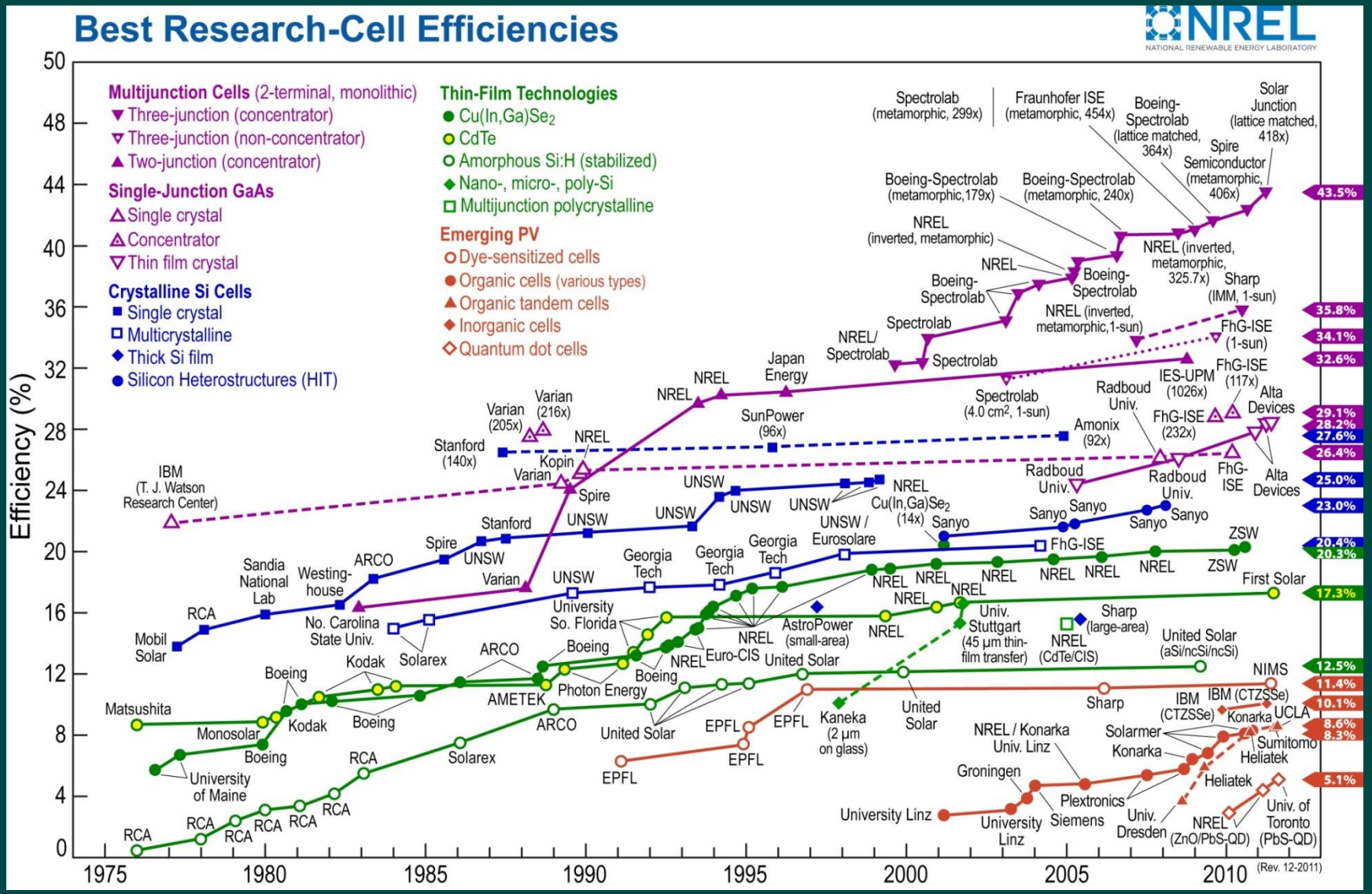

SBIRS - 4 GEO satellites, 2 HEO payloads

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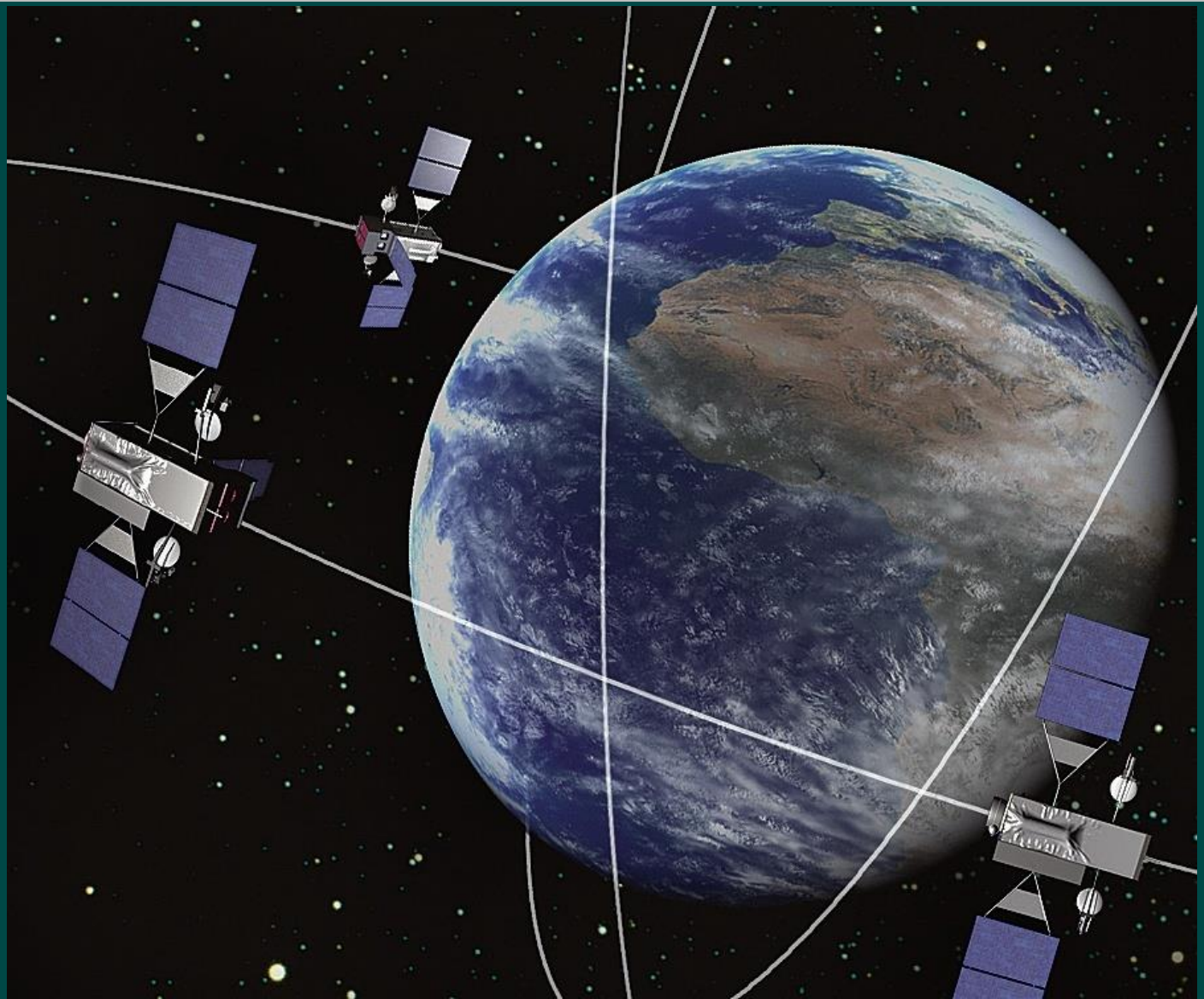

SBIRS System Architecture

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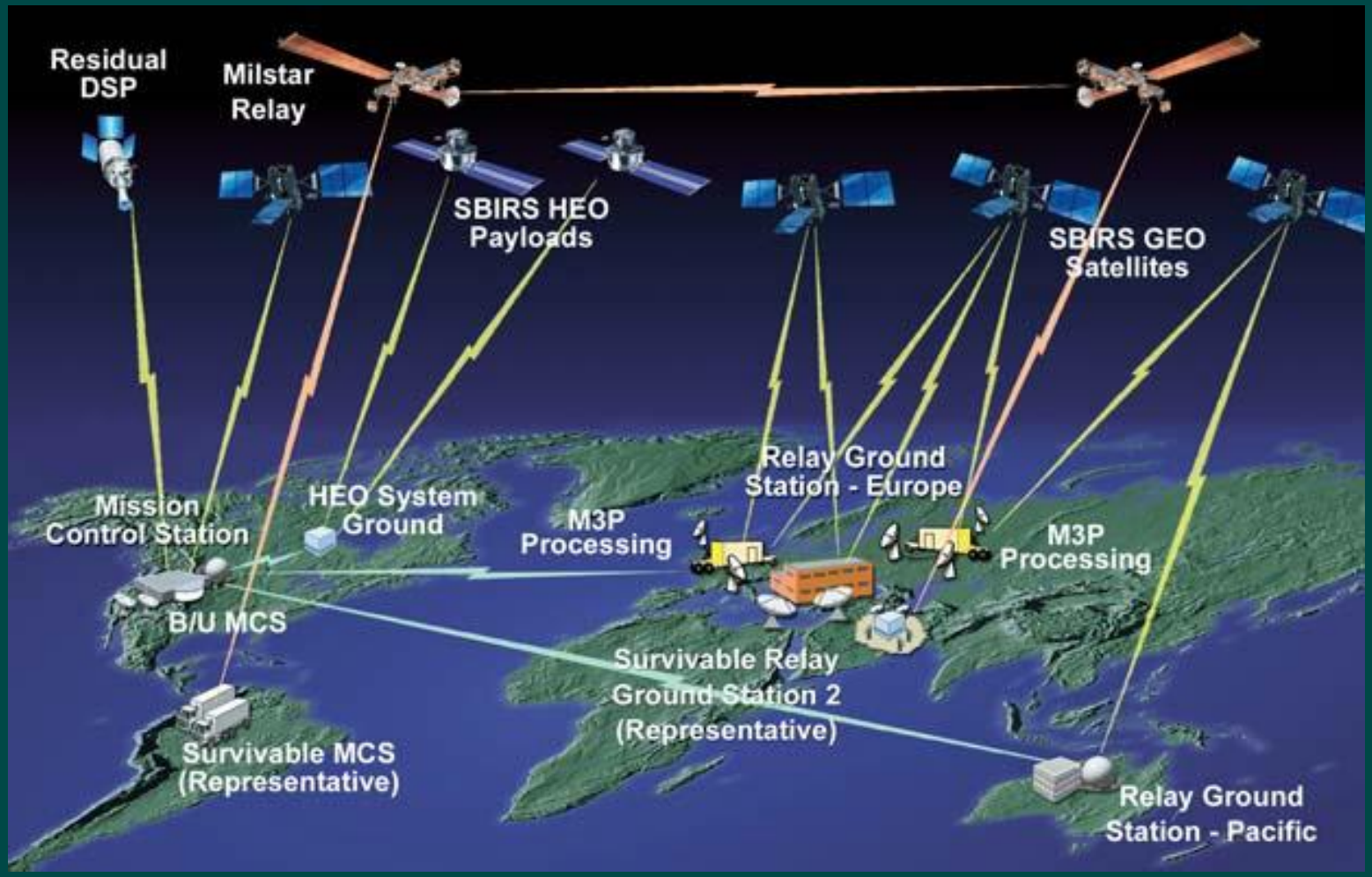

Defence Support Program (DSP)

GEO & HEO satellite constellation detecting missile launch

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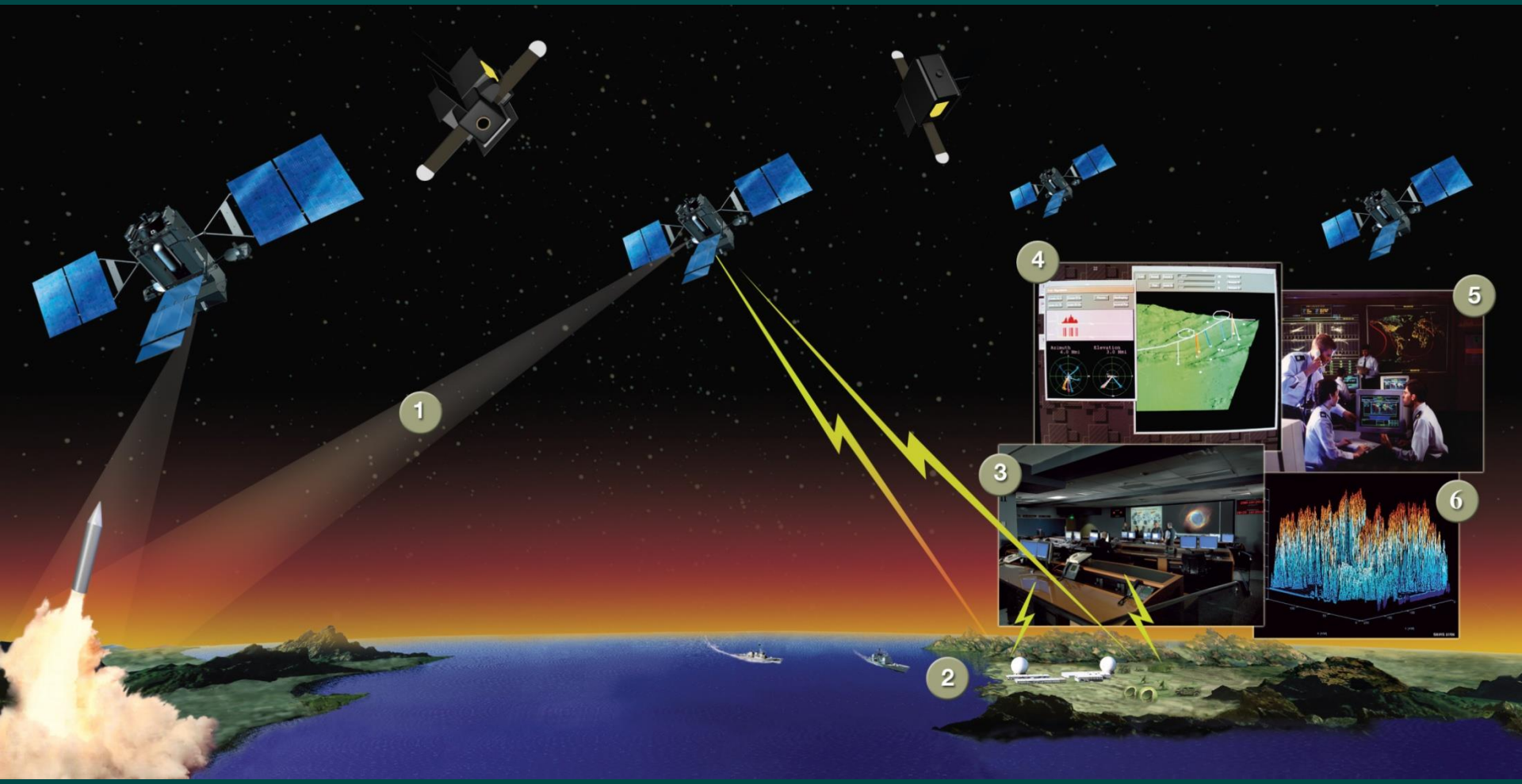

3. The Mission Control Station

5. Air Force Space Command

Ground Station Features

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- Manages SBIRS objective constellation of 4 GEO satellites, 2 HEO payloads, and legacy Defence Support Program (DSP) satellites
- Key functions
  - Mission planning/payload tasking
  - Constellation management/TT&C
  - Mission processing
  - Event reporting and data distribution
  - Ground control

LEO (1350 km) infrared observation satellites working in pairs

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BOOST PHASE

MIDCOURSE PHASE

RE-ENTRY PHASE

Two Northrop Grumman Space Tracking and Surveillance System (STSS) satellites on-orbit, demonstrating capabilities required for birth-to-death tracking of ballistic missiles and other cold objects in space.

Integrated Detection Systems

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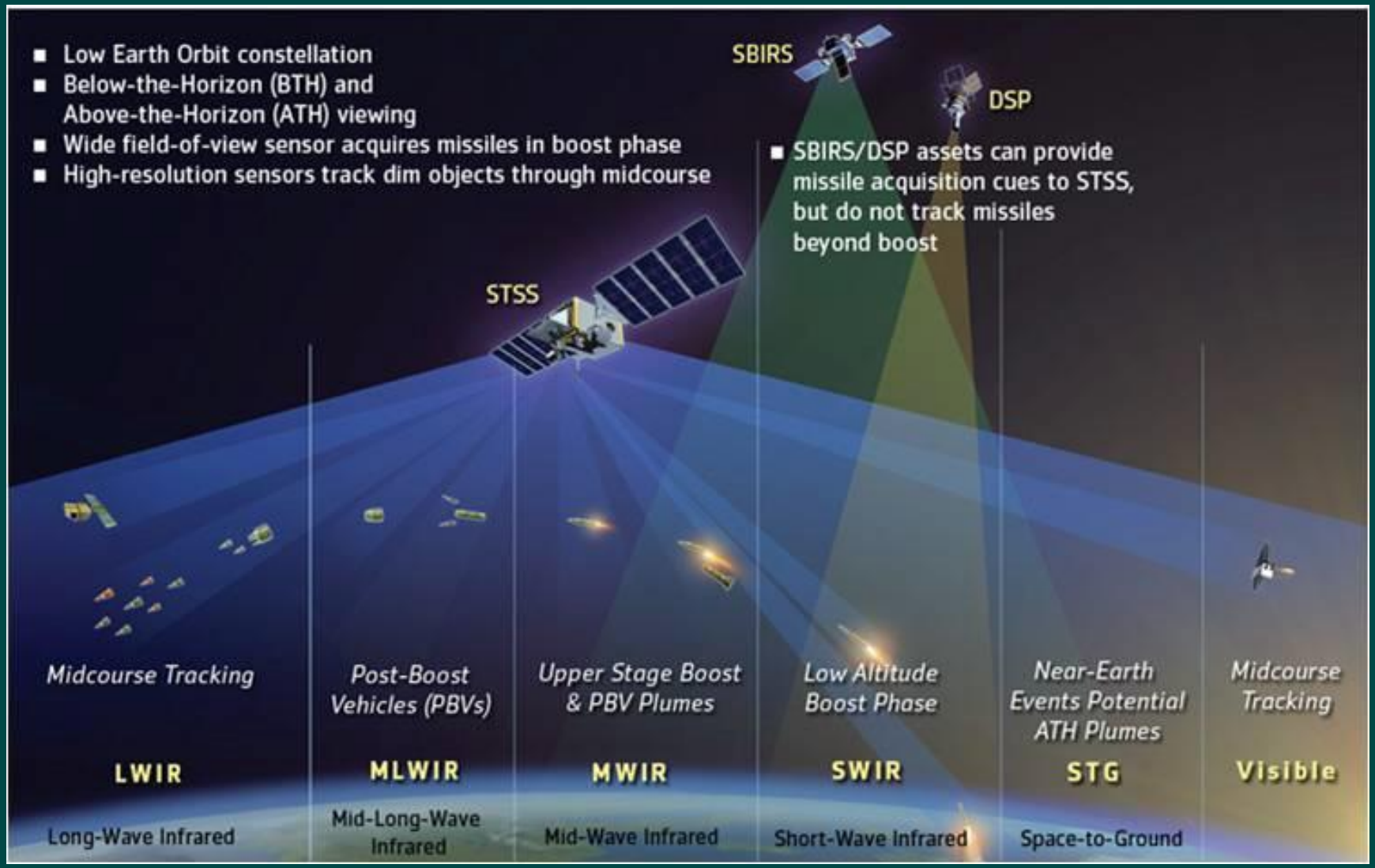

Defence Meteorological Satellite Program (DMSP)

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- Defence Meteorological Satellite Program (DMSP) satellites "see" such environmental features as clouds, bodies of water, snow, fire, and pollution in the visual and infrared spectra.
- Scanning radiometers record information which can help determine cloud type and height, land and surface water temperatures, water currents, ocean surface features, ice, and snow.
- Communicated to ground-based terminals, the data is processed, interpreted by meteorologists, and ultimately used in planning and conducting U.S. military operations worldwide.

Wideband Global SATCOM (WGS)

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- WGS is designed for coverage, capacity and connectivity, and can process more than 3.6 gigabits per second of data – more than 10 times that of the previous system.

- Operating at both X-band and Ka-band, the system will enable networks for tactical Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR).

WGS Bandwidth

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- WGS supports communication links throughout the allocated 500 MHz of X-band and 1 GHz of Ka-band spectrum.
- Through frequency re-use and digital channelization, each WGS payload can exploit more than 4.8 GHz of usable communications bandwidth.

Communication Flexibility

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- The WGS design includes 19 independent coverage areas – 10 Ka-band and 8 X-band spot beams can be positioned anywhere in the field of view of each satellite.

- Full-Earth coverage in X-band is also provided. Use of phased array technology allows the eight X-band beams to be steered and shaped to apply gain and power exactly where it’s needed.

WGS satellite communications - Ka Band video transmit and receive

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DTN News: General Dynamics' Warrior Antenna Terminals Certified To Operate On Wideband Global SATCOM Network. Two General Dynamics SATCOM Technologies' Warrior antenna terminals are now certified by the U.S. Army to use the Ka-band frequency to access the Wideband Global SATCOM (WGS) network, enabling warfighters to transmit and receive video, multimedia imagery and data faster and more securely.

WGS-4 scheduled for Jan. 19, 2012 launch from Cape Canaveral

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EL SEGUNDO, Calif., Jan. 18, 2012 — Boeing [NYSE: BA] today announced that the fourth Wideband Global SATCOM (WGS) satellite the company is delivering to the U.S. Air Force has successfully completed prelaunch testing and is ready for launch. WGS-4, the first spacecraft in the program's upgraded Block II series, is scheduled to launch at 7:38 p.m. Eastern time on Jan. 19 aboard a United Launch Alliance Delta IV vehicle from Cape Canaveral Air Force Station, Fla.

Onboard Router

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- Communications between users is enhanced using the digital channelizer, which allows for very efficient use of a satellite's bandwidth.
- It divides the uplink bandwidth into nearly 1,900 independently routable sub-channels, providing the connection from any uplink coverage area to any downlink coverage area.

1,900 independently routable sub-channels

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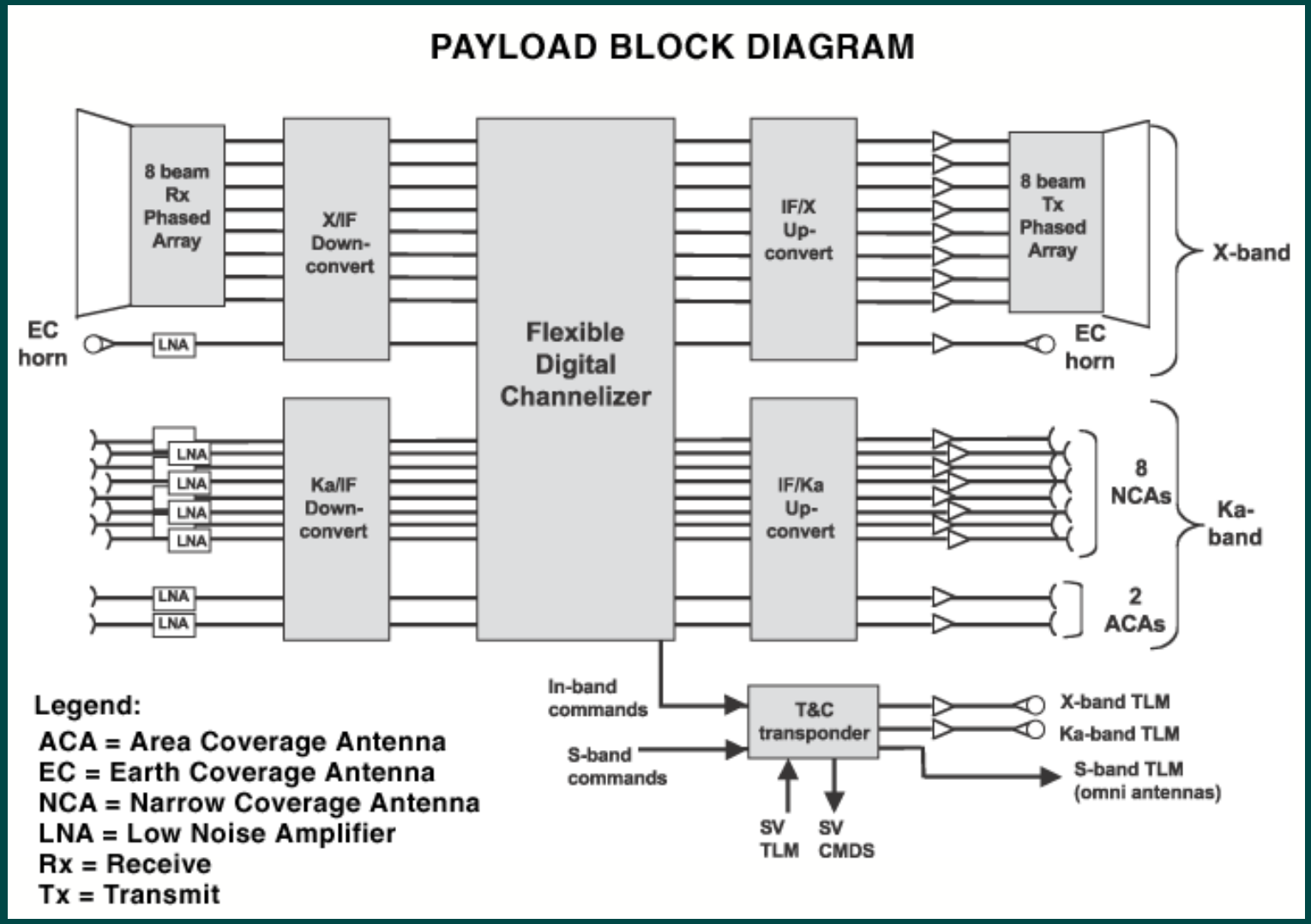

Internet Routing in Space (IRIS) Payload Architecture

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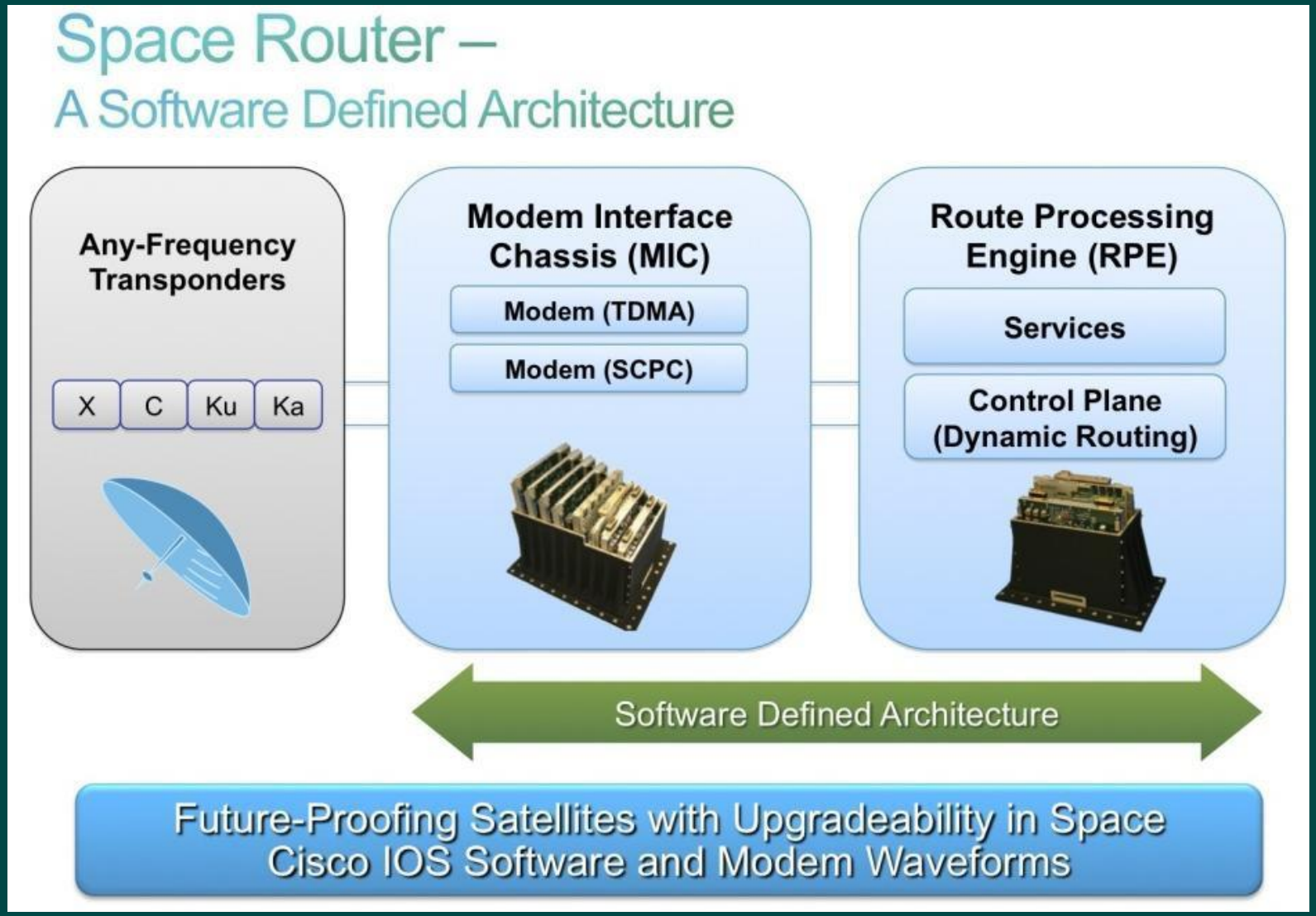

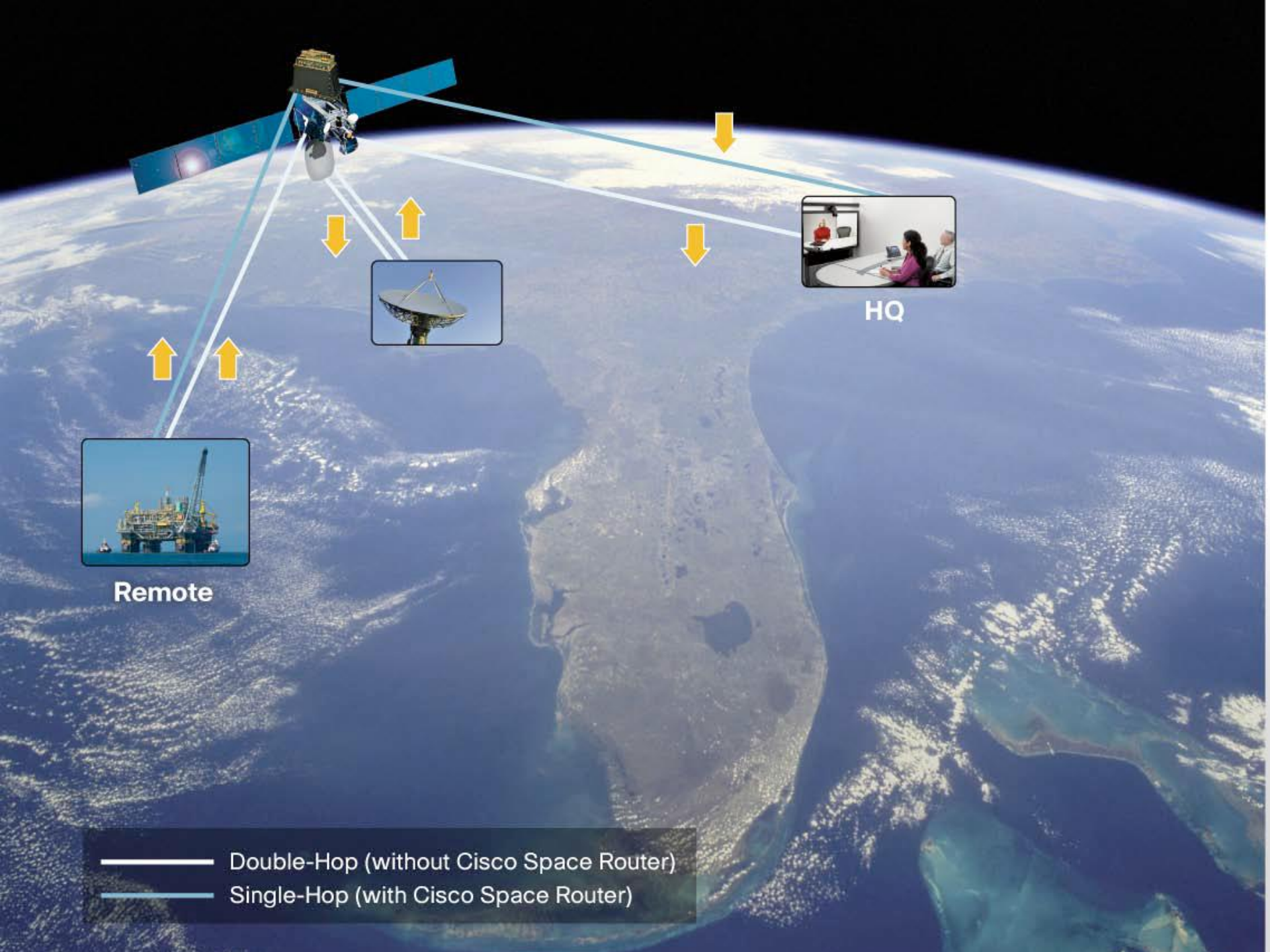
HQ
Remote
Double-Hop (without Cisco Space Router)
Single-Hop (with Cisco Space Router)

Internet Routing in Space

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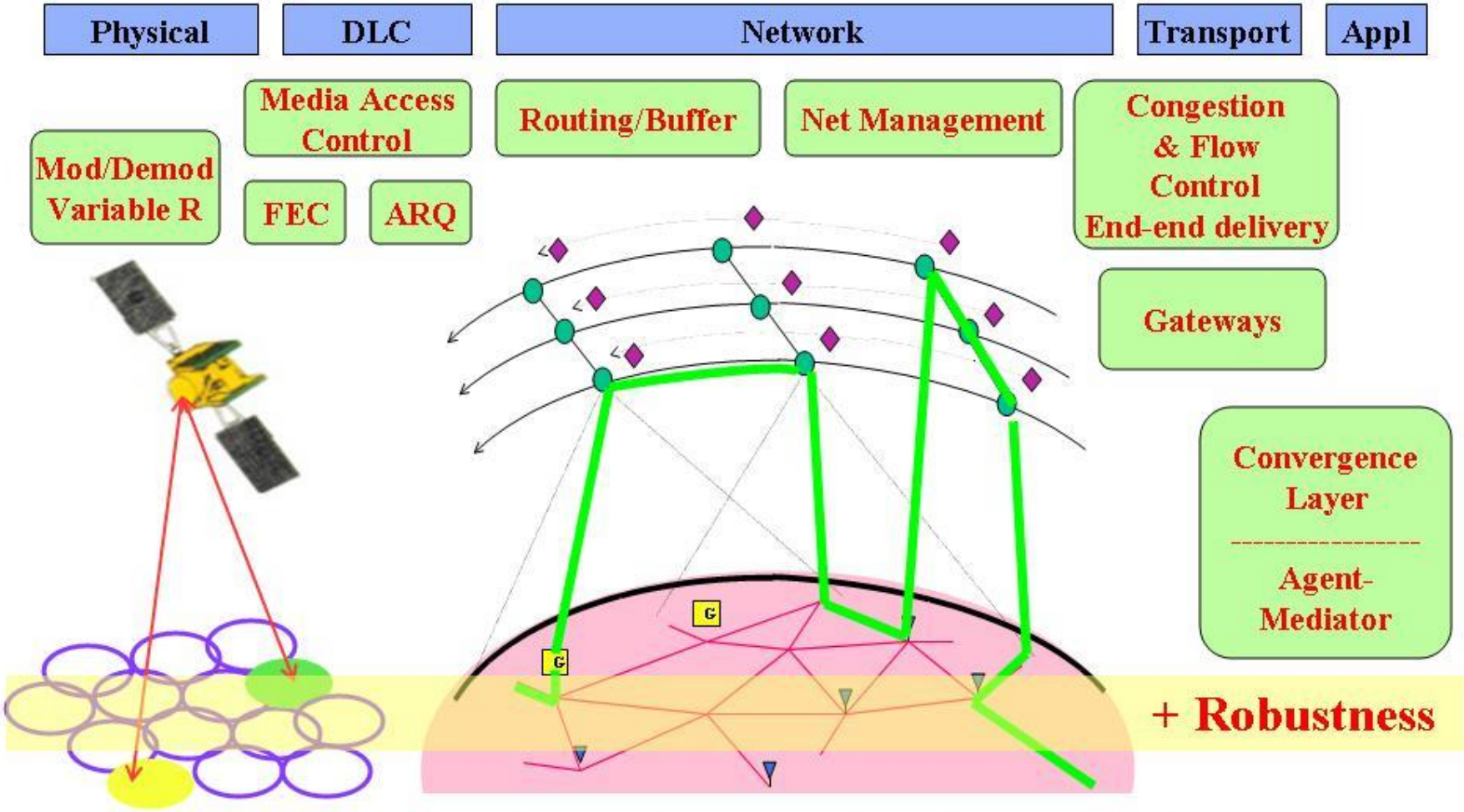
Satellite Networks



- *Dynamic Capacity*
- *Agile beams*
- *MAC*
- *Fading*

- ***Dynamic routing:*** *deterministic & stochastic*
- ***Heterogeneous network:*** *Satcom, fiber, wireless*
- ***Differentiated services:*** *policy-based, time-deadline, .*

- *Satellite resources extremely precious*

Ground Based Control Centres

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- The WGS communications payload is controlled from four Wideband Satellite Operations Centers, using ground-based control elements provided by Boeing.

- Platform control is conducted from Schriever AFB using mission-unique software designed specifically for this program by Boeing in concert with the USAF's Command and Control System-Consolidated (CCS-C).

EADS Astrium Ka-SAT, 6.1 Tonnes at launch, 15 year lifetime, 11 kW

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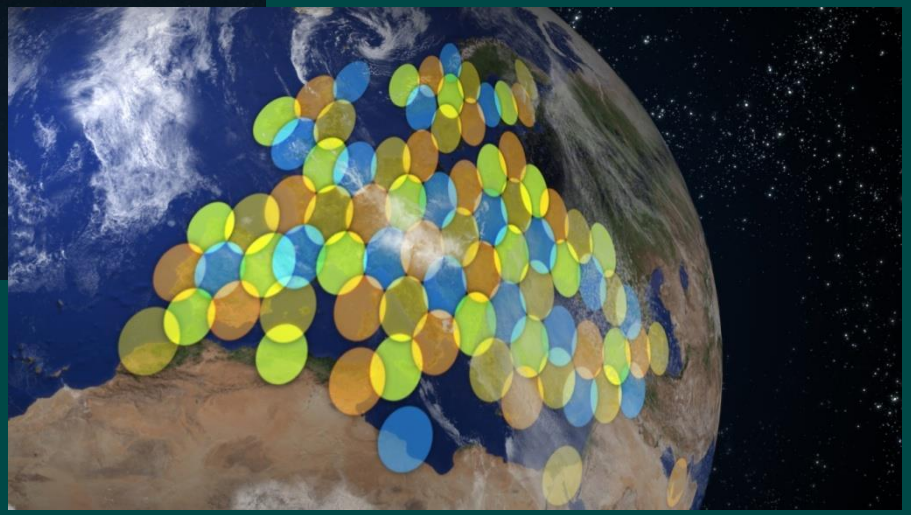
The British military's Skynet 5 satellite system is based on this. The spacecraft is part of a £3.6bn system that will deliver secure, high-bandwidth communications for UK and allied forces.

Eutelsat's Ka-SAT is the world's most powerful satellite ever built, with a total capacity of more than 70 Gbps, 35 times the throughput of traditional Ku-band satellites.



KA-SAT will provide ubiquitous complete coverage of Europe and the Mediterranean Basin through its 82 spot beams in Ka-band

ViaSat-1 in the Compact Antenna Test Range (CATR) - Space Systems/Loral

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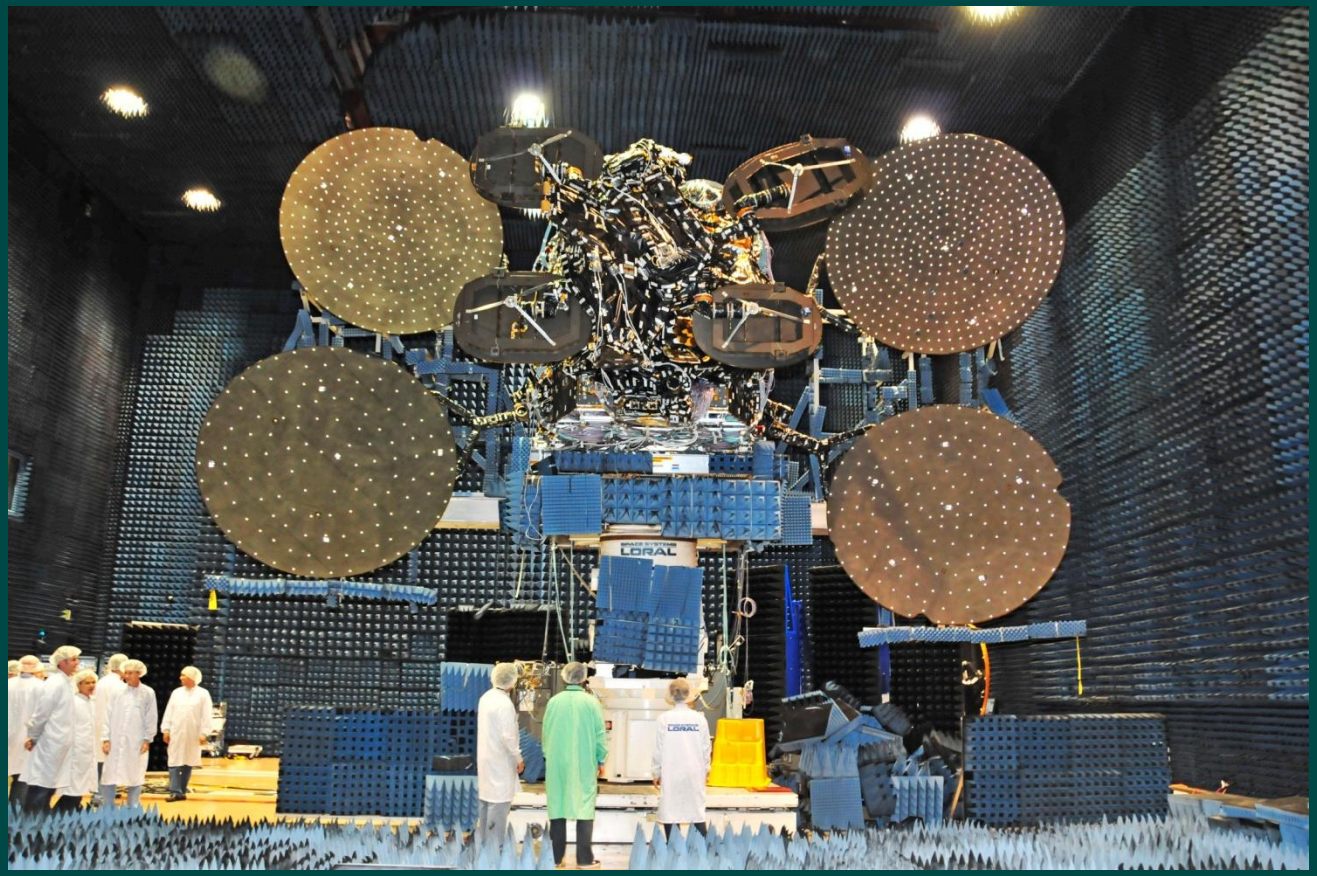

ViaSat-1, which will be positioned at 115.1 degrees West longitude, is expected to provide more than 100 gigabits per second throughput in the Ka band, mostly for use in the West Coast of the U.S. and east of the Texas panhandle. The satellite has 72 spot beams, with 63 in the U.S. and nine over Canada.

Predator - Unmanned Aerial Vehicle (UAV)

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UHF and VHF radio relay links, a C-band line-of-sight data link which has a range of 150nm and UHF and Ku-band satellite data links.

The vehicle carries electro-optical and infrared cameras and a synthetic aperture radar.

The two-colour DLTV television is equipped with a variable zoom and 955mm Spotter. The high resolution FLIR has six fields of view, 19mm to 560mm.

Global Hawk High-Altitude, Long-Endurance, Unmanned Reconnaissance Aircraft, USA

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Performance:

Maximum Endurance: 42 hours

Loiter Velocity = 343kt

Maximum Altitude: 65,000ft

Communications:

Satellite Comms Datalink

1.5Mbps, 8.67Mbps, 20Mbps, 30Mbps, 40Mbps, 47.9Mbps

Line of Sight (LOS) Datalink

137Mbps

Synthetic Aperture Radar (SAR) - 1m/0.3m resolution (WAS / Spot)

Moving Target Indicator - 4kt minimum detectable velocity

Electro-Optical - NIIRS 5.5 / 6.5 (WAS/Spot)

Infrared - NIIRS 5.0 / 6.0 (WAS/Spot)

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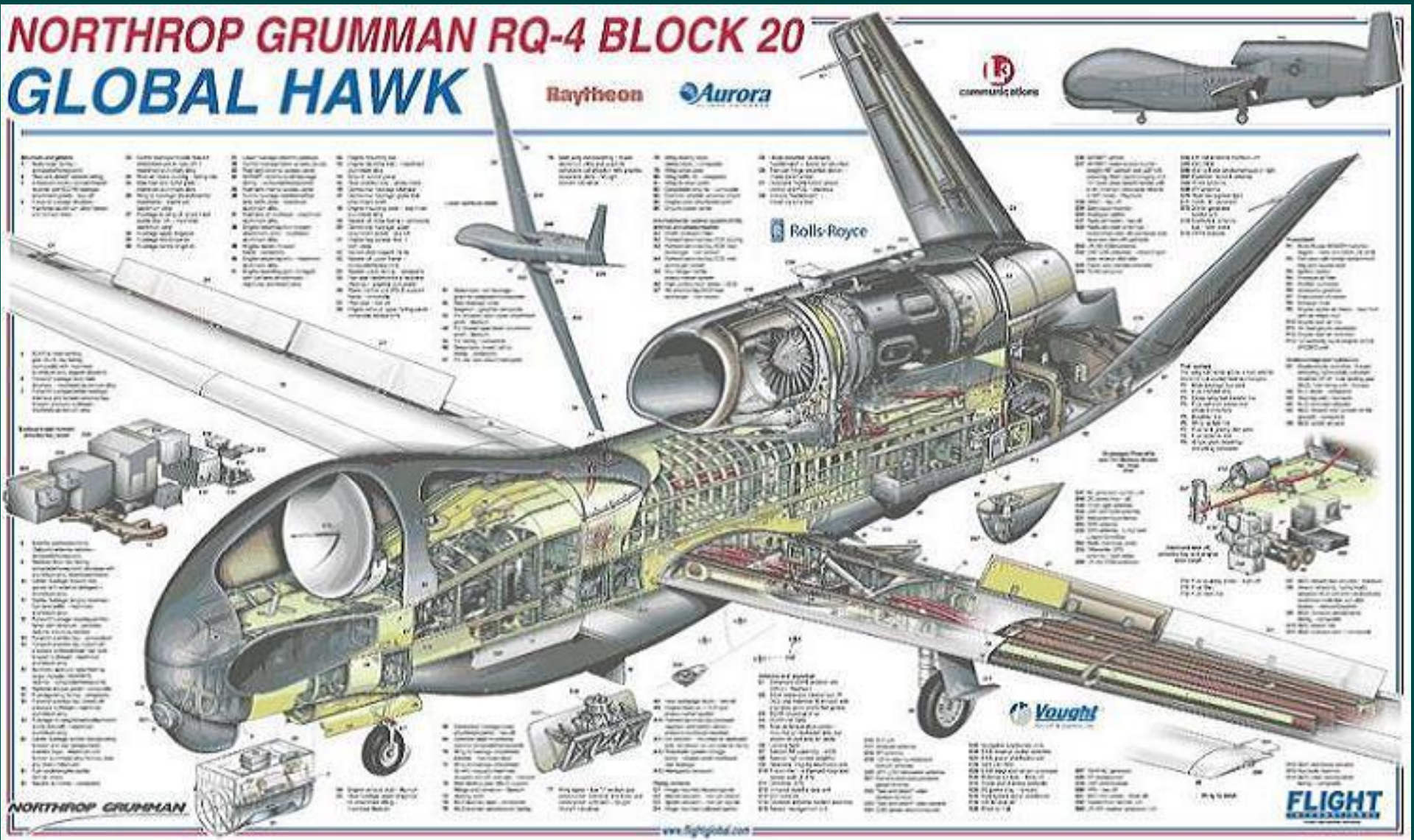

High Altitude Spy Planes

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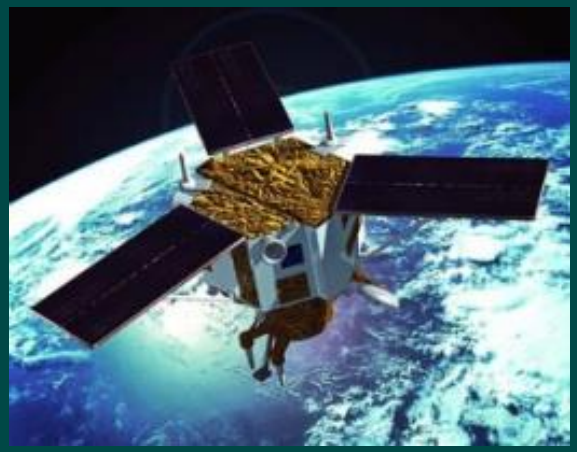
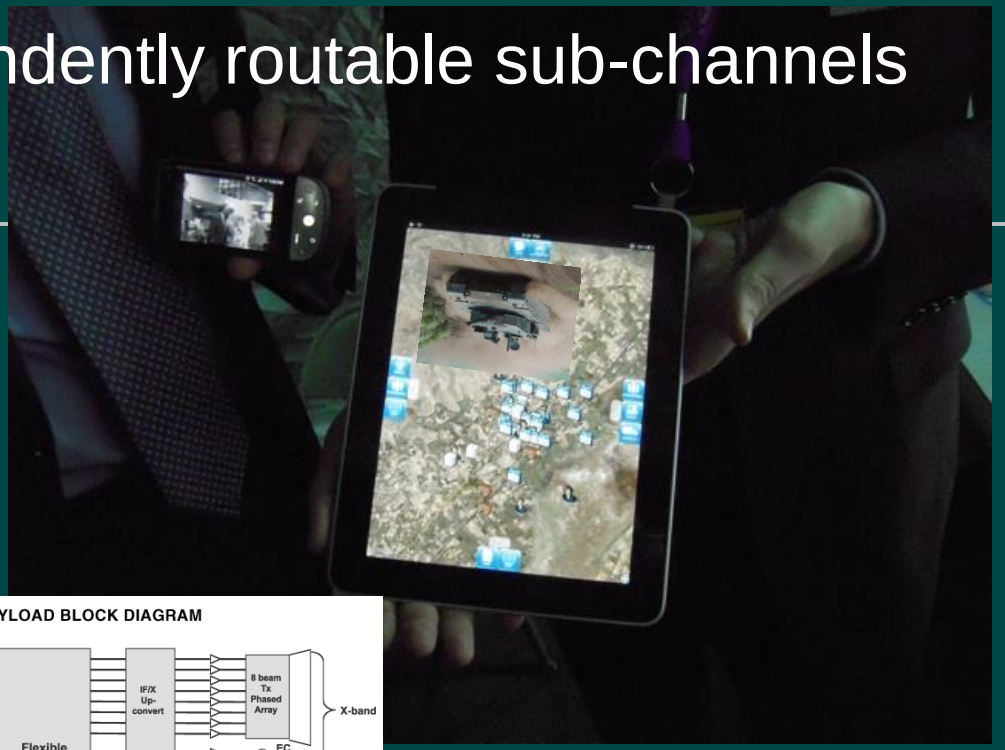
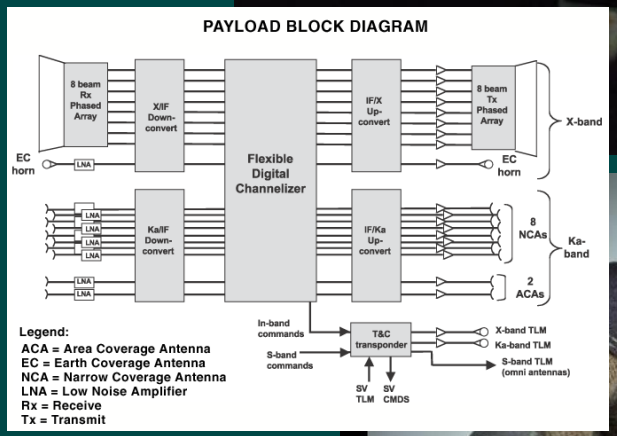


Mach 3.4 – 2,242 mph @ 85 - kft

WGS has 1,900 independently routable sub-channels





Ubiquitous Sonar Surveillance Systems

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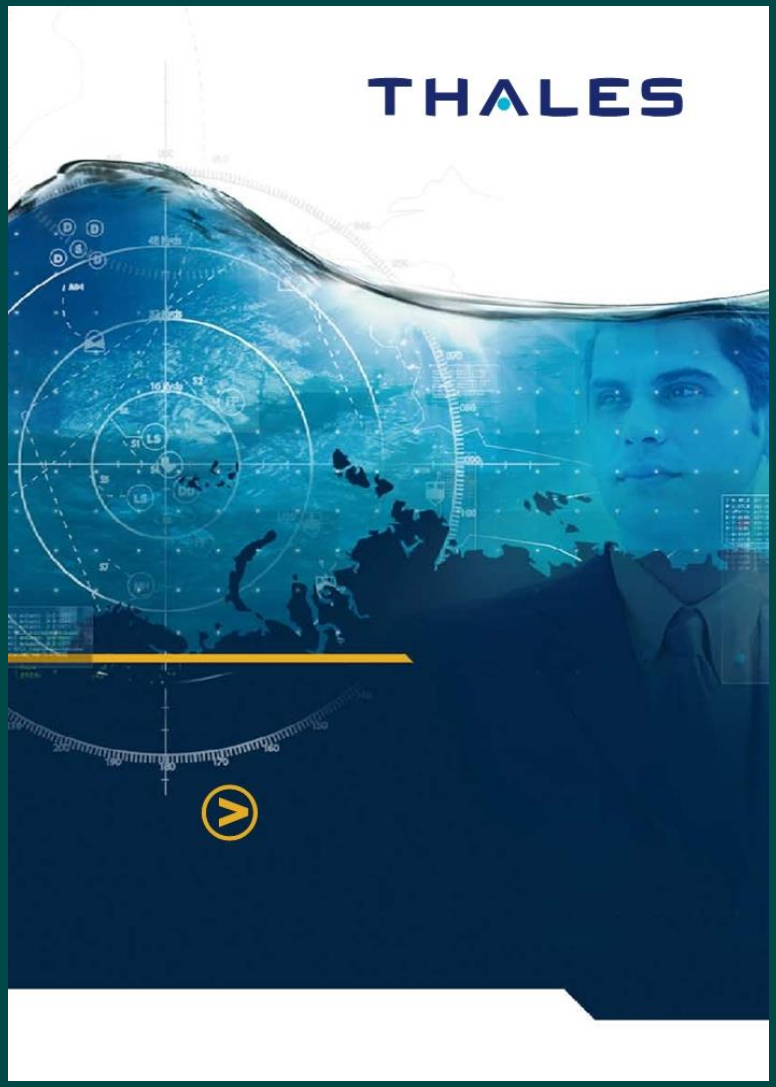

Some Sonar Systems

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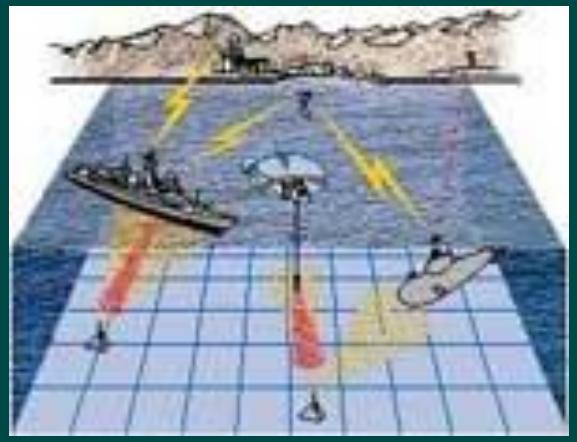

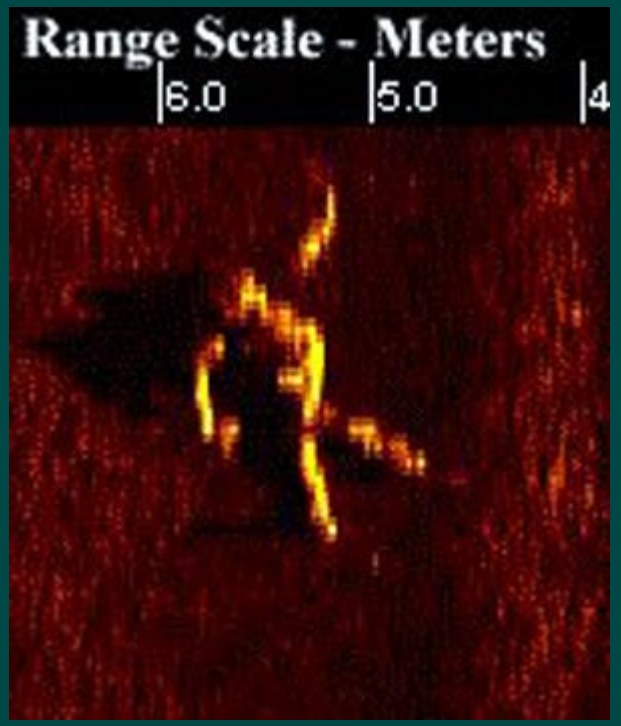

MST’s sonar systems are able to accurately identify small submerged objects such as discarded evidence or corpses, making it ideal for law enforcement investigations

Sonar Systems

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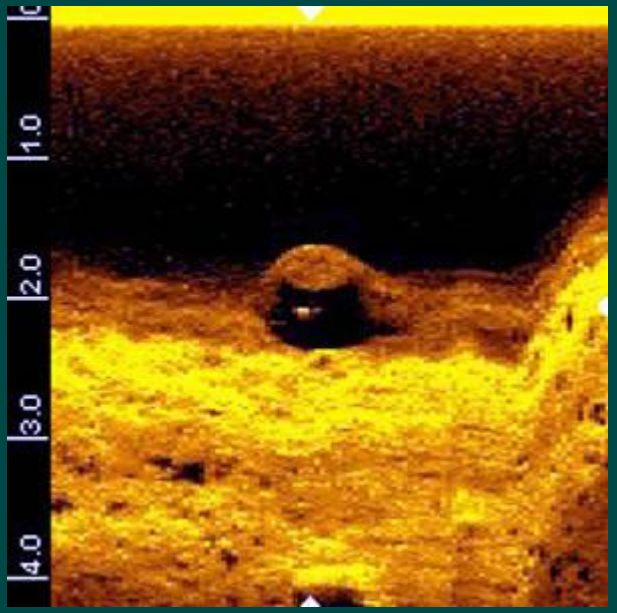
Thales CAPTAS - Combined Active / Passive Towed Array Sonar - is a family of low frequency variable depth ASW sonars for surface ships



MST's sonar detection systems can accurately image small underwater threats such as mines.

The Intelsat Satellite Network

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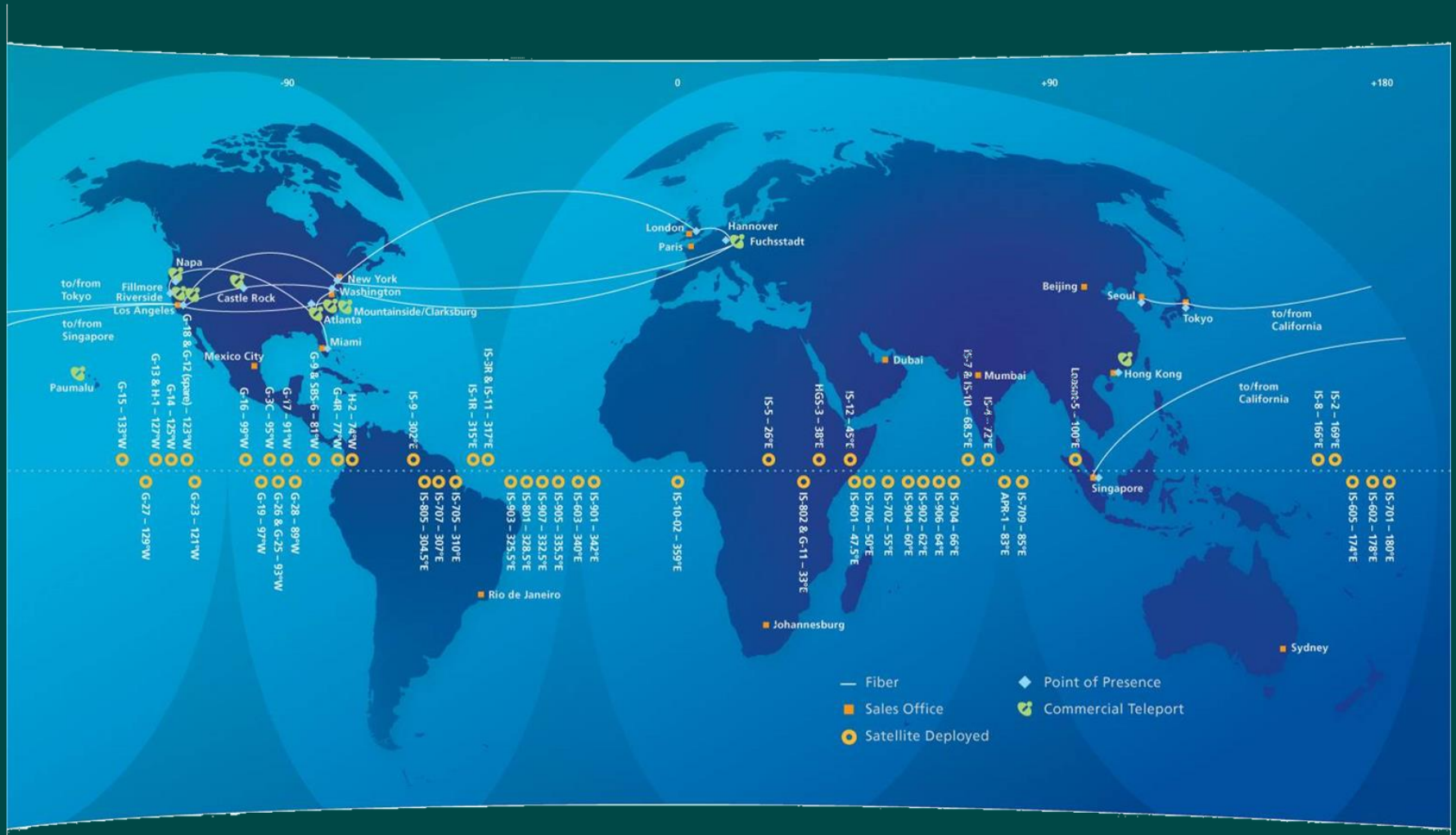

Intelsat GXS® Fiber Network

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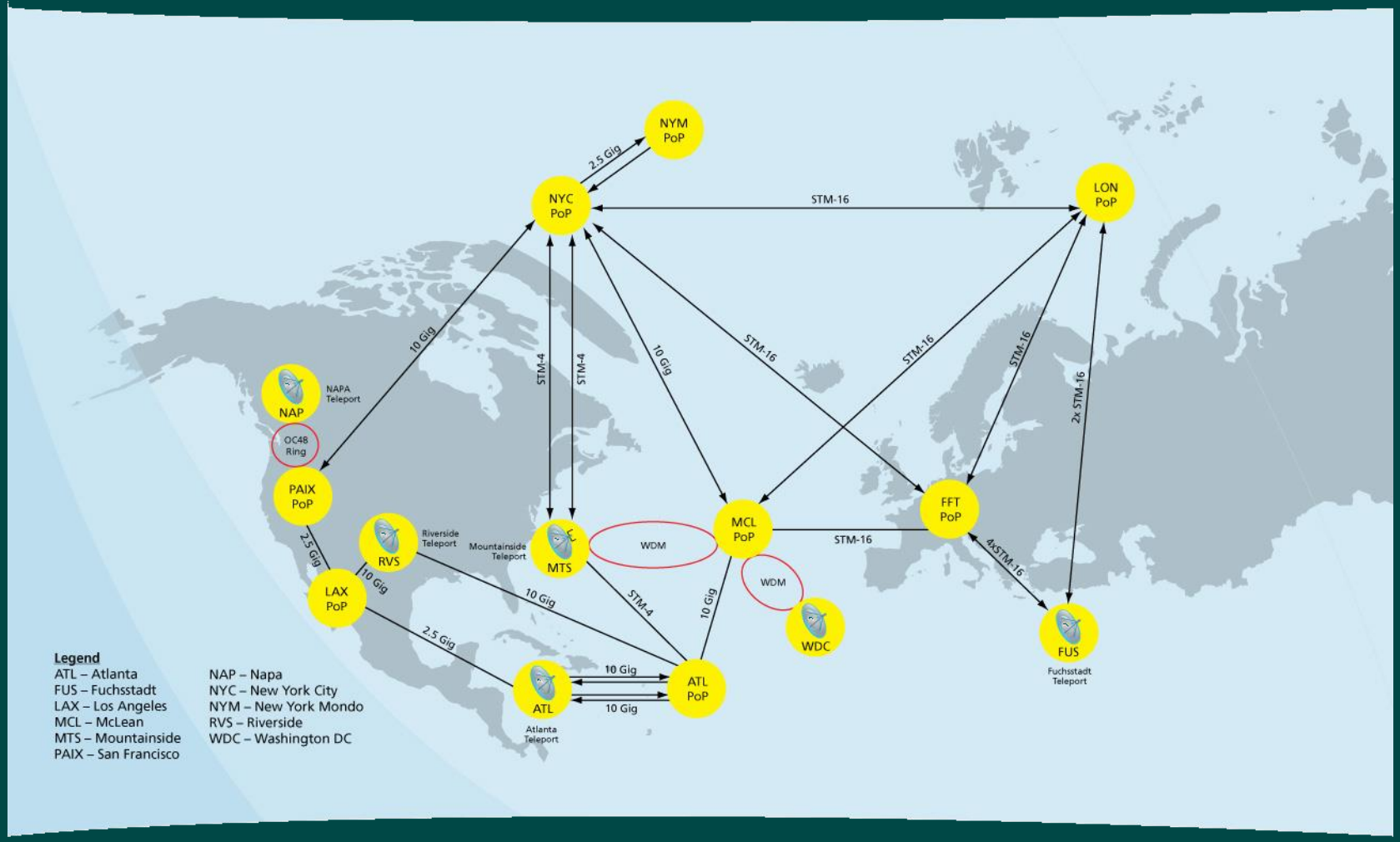

Very Small Aperture Terminal (VSAT)

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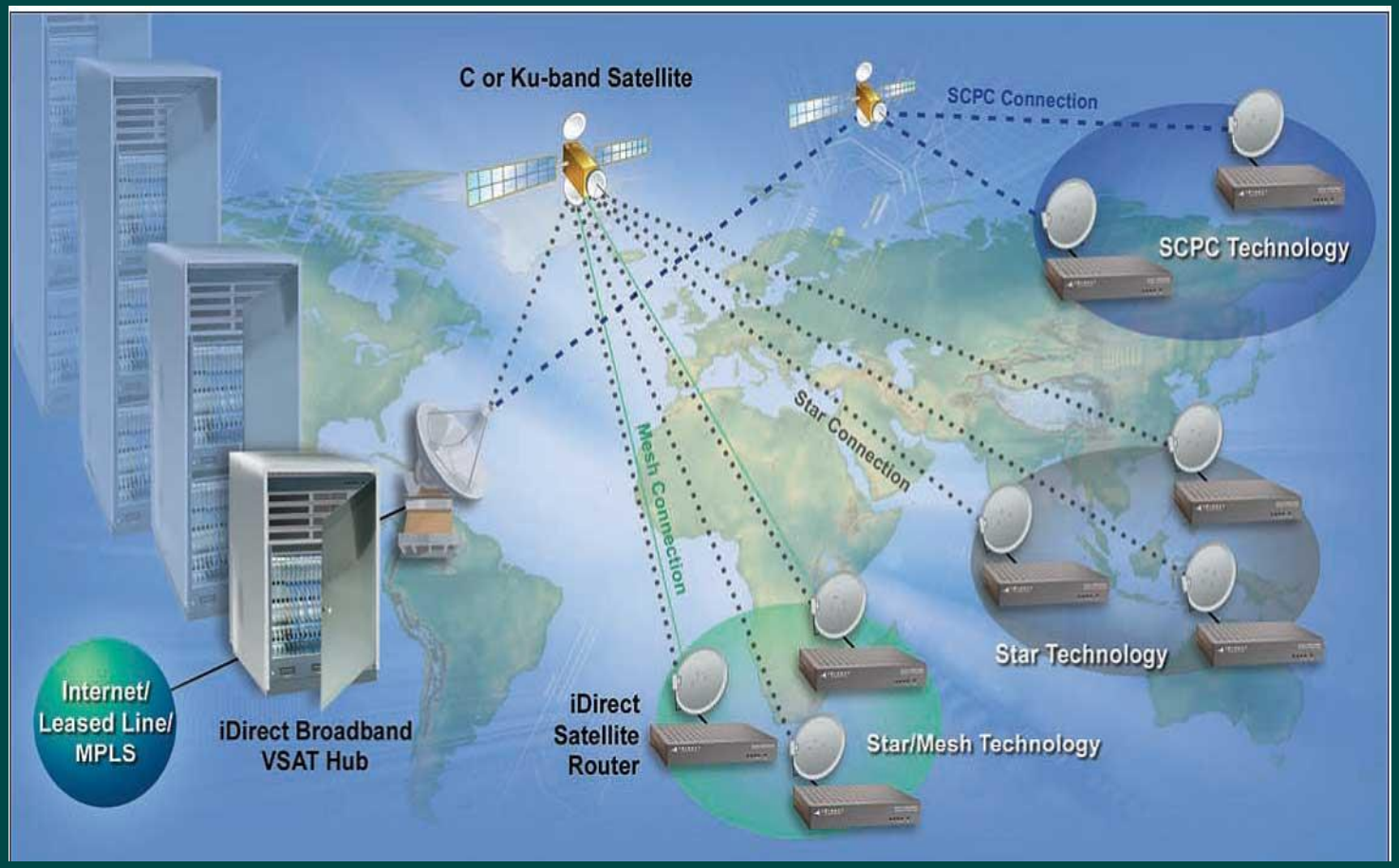

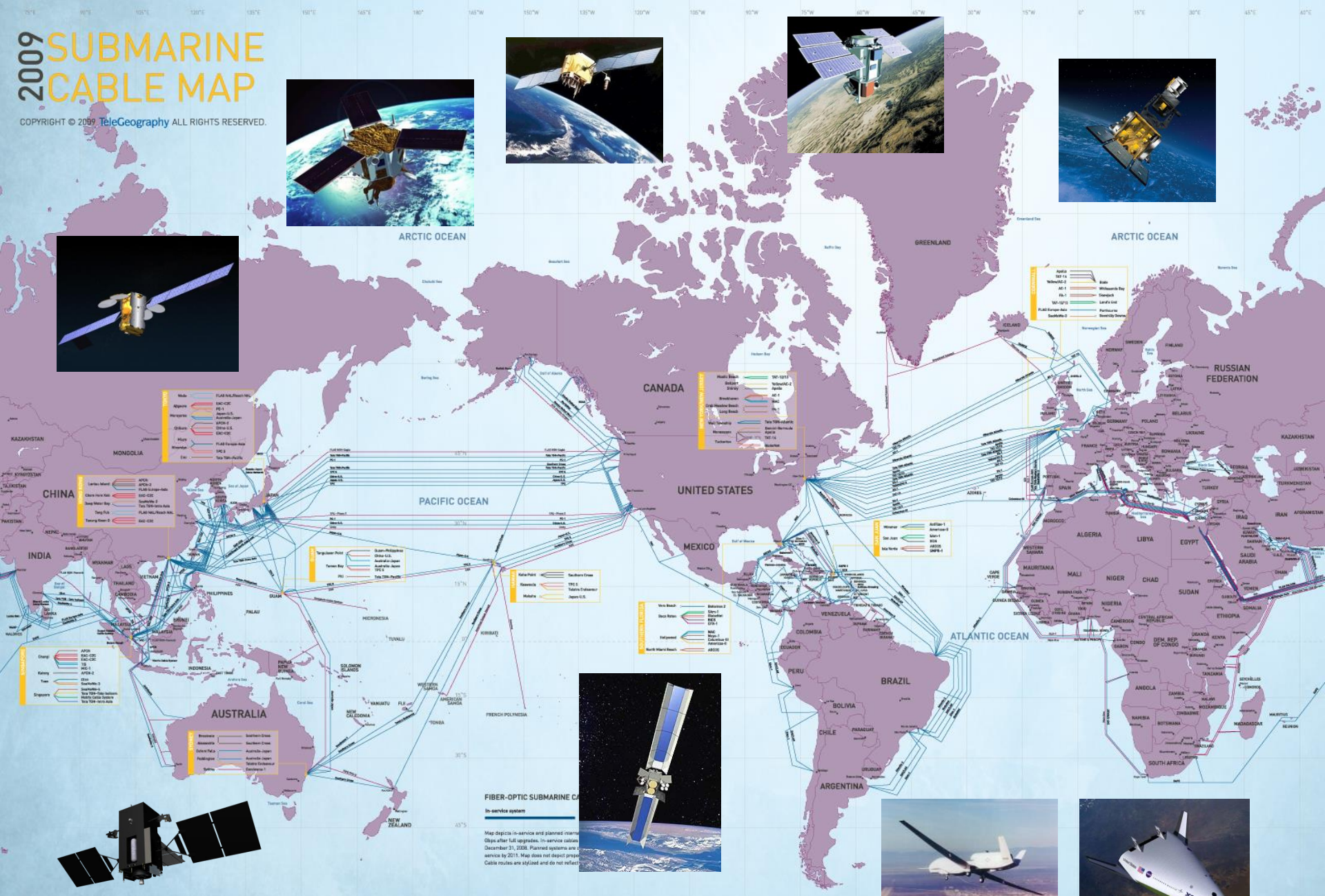

Global Data Integration Technology

Use of the Global Fibre Network

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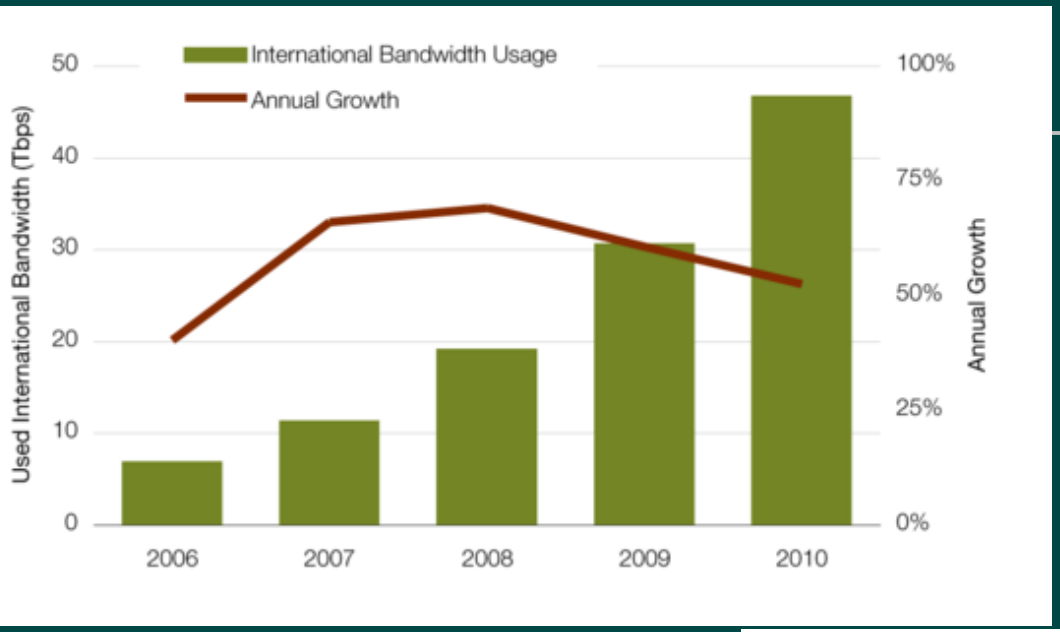

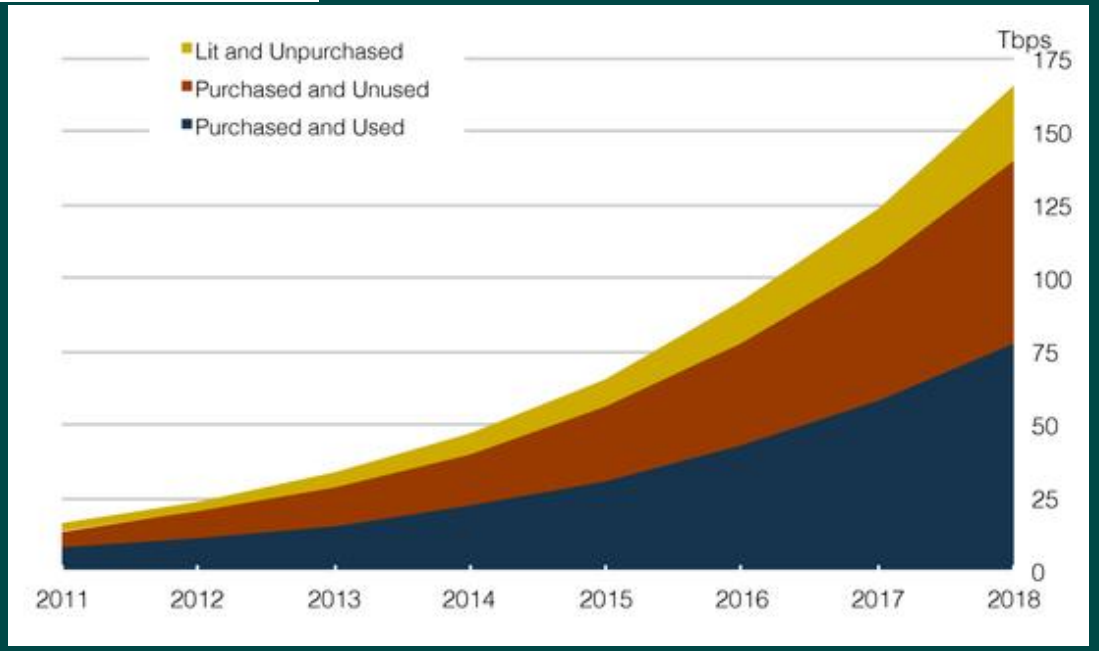

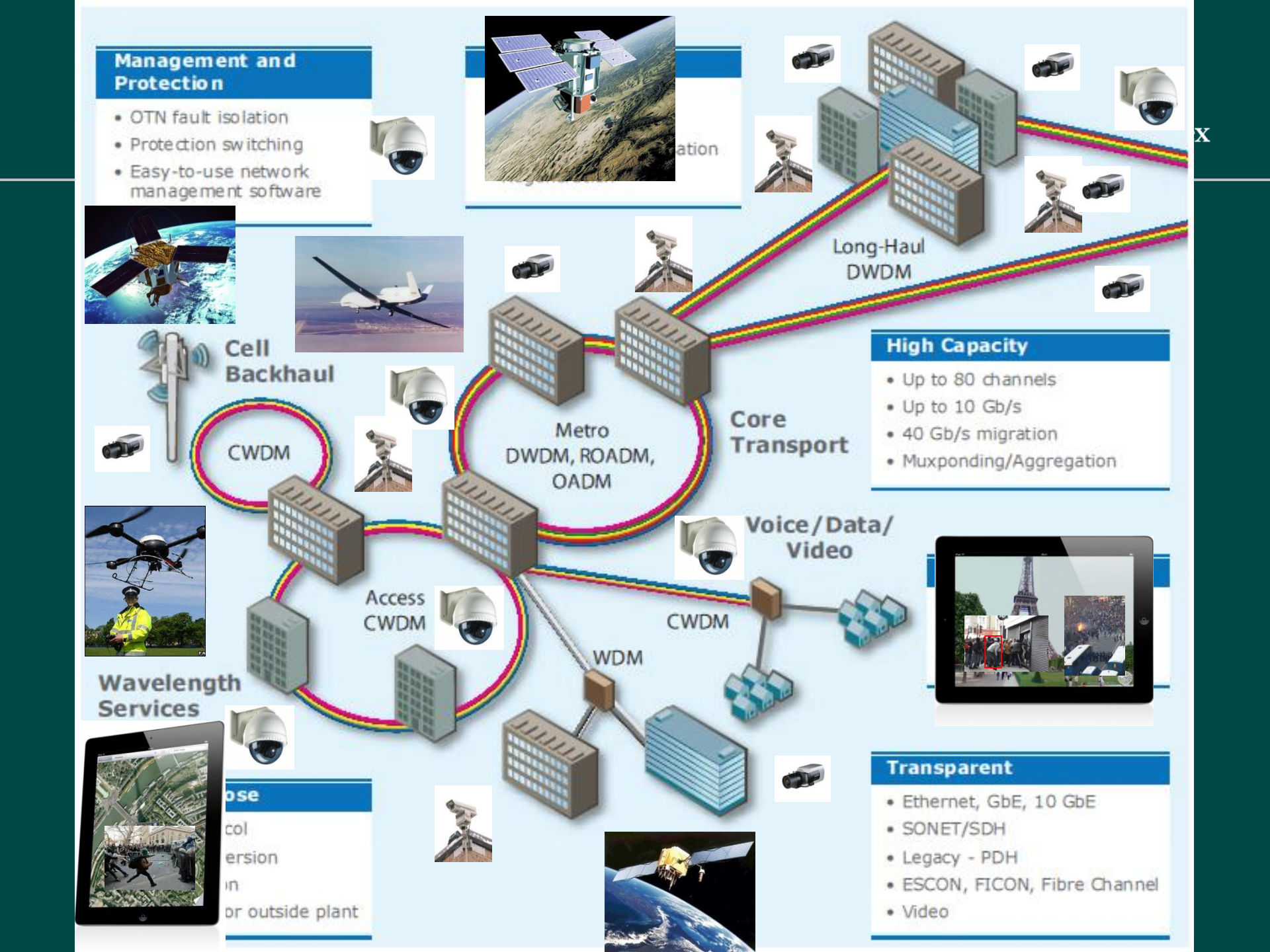
Management and Protection
• OTN fault isolation
• Protection switching
• Easy-to-use network management software
Long-Haul DWDM
Cell Backhaul
CWDM
Metro DWDM, ROADM, OADM
Core Transport
High Capacity
• Up to 80 channels
• Up to 10 Gb/s
• 40 Gb/s migration
• Muxponding/Aggregation
Voice/Data/ Video
Access CWDM
CWDM
WDM
Wavelength Services
Transparent
• Ethernet, GbE, 10 GbE
• SONET/SDH
• Legacy - PDH
• ESCON, FICON, Fibre Channel
• Video

Intel's 50Gbps silicon laser transmitter, at bottom right, and optical receiver, at top left

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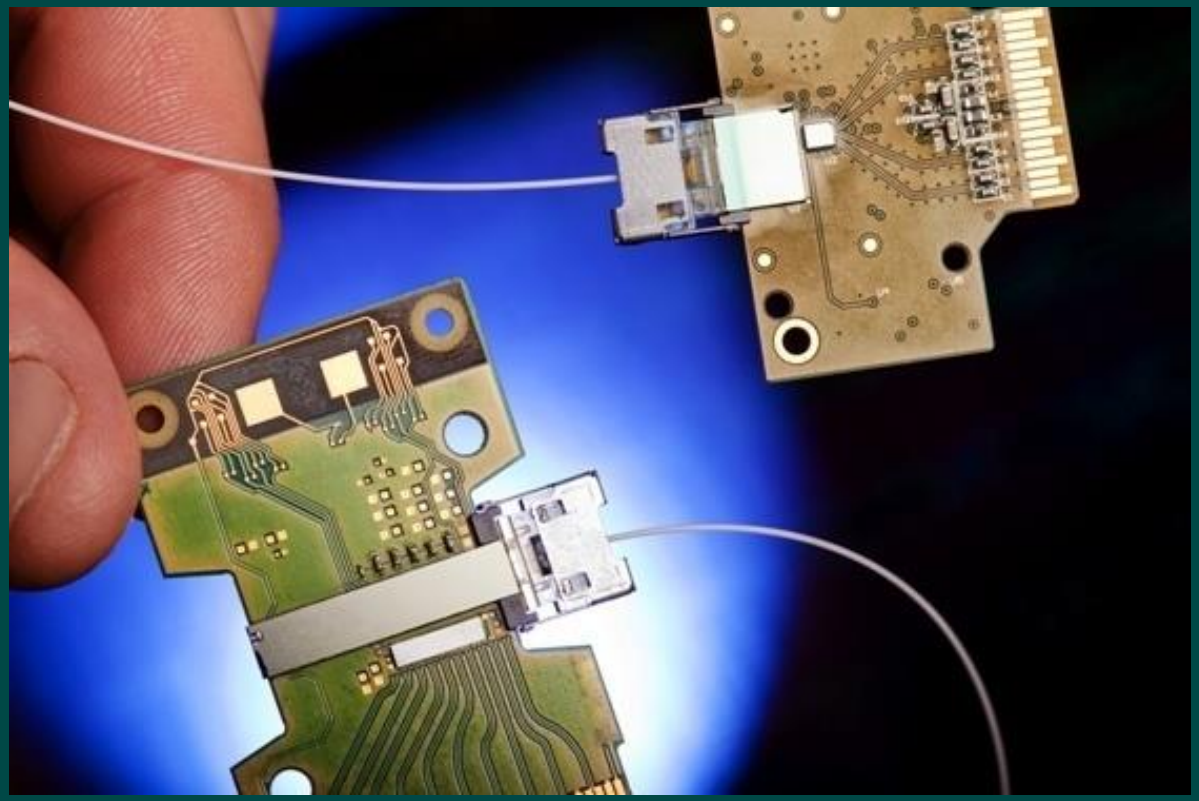

Intel has debuted the prototype of a high-speed fibre optic data system based on silicon chips with integrated lasers and detectors, which it says can revolutionise affordable data communications across IT

Six main building blocks

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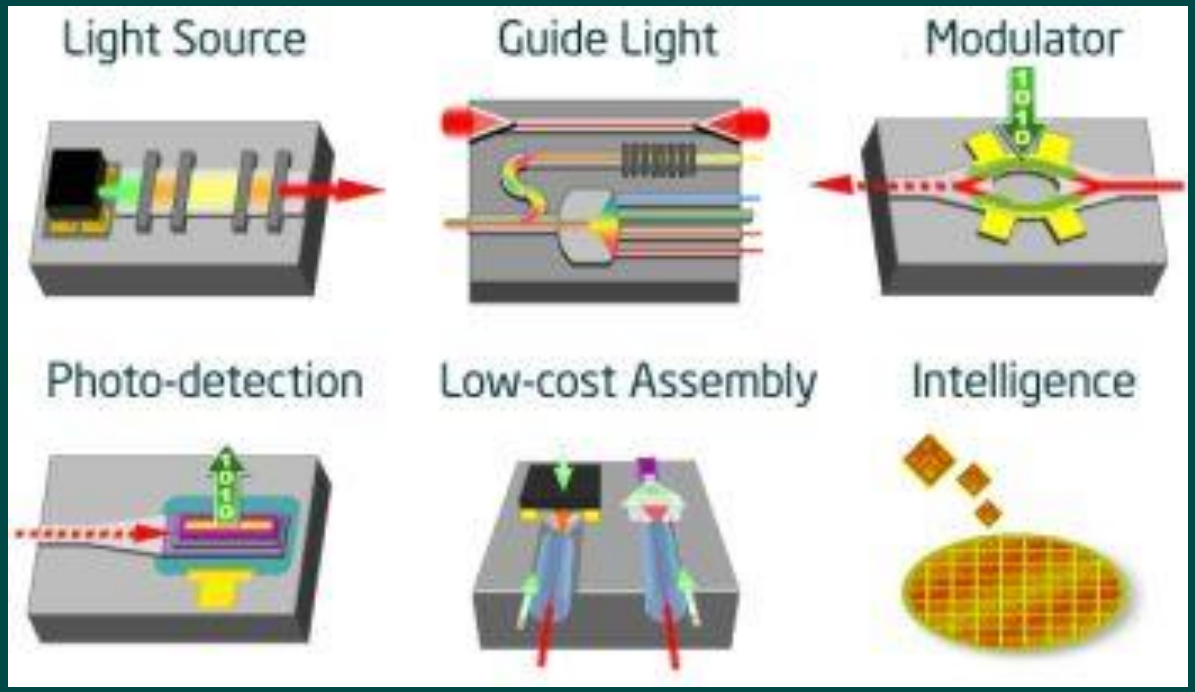

1) generate the light,
2) selectively guide and transport it within the silicon,
3) encode the light,
4) detect the light,
5) package the devices,
6) intelligently control all of these photonic functions

Lithographically Manufactured Silicon Laser

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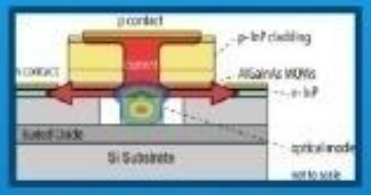
Hybrid Silicon Laser
(Developed with UCSB)

- Creating a Silicon-based laser by bonding a III-V material (Indium Phosphide) onto Silicon

InP bonded to Si



Cross Section of Hybrid Laser


SEM of Cross Section

- InP emits light when electrically stimulated
- Light bounces back and forth in silicon, and is amplified by the InP based material
- Mirrors are gratings etched into the silicon
  - Grating pitch defines the laser wavelength


One bond, no alignment needed

With ONE bond 1000's of lasers are aligned
Can produce different wavelengths by simple lithography

intel

Gratings tune the wavelength

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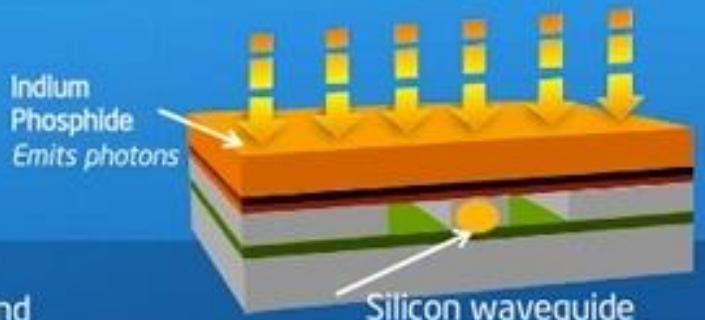
Key Technology: Hybrid Silicon Laser

Research collaborations with Prof. John Bowers and team at UCSB paved way for Hybrid Silicon Laser breakthrough



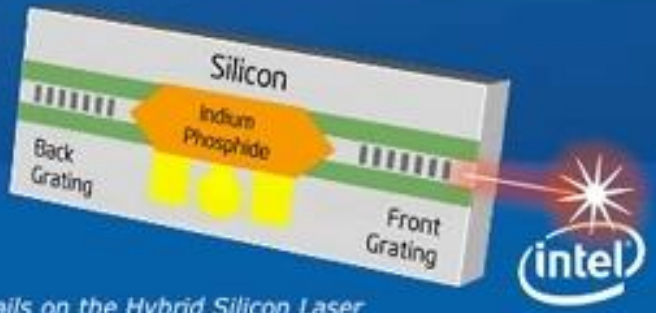
2006

-Intel & UCSB develop a unique process to fuse InP to Silicon

-Can create 1000s of lasers with one bond

2008

Added etched gratings into waveguides that act as "mirrors," that are used to create different wavelengths of light



11

See backup slide 21 for more details on the Hybrid Silicon Laser

PC Manufacturing Technology

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Terabit data rates

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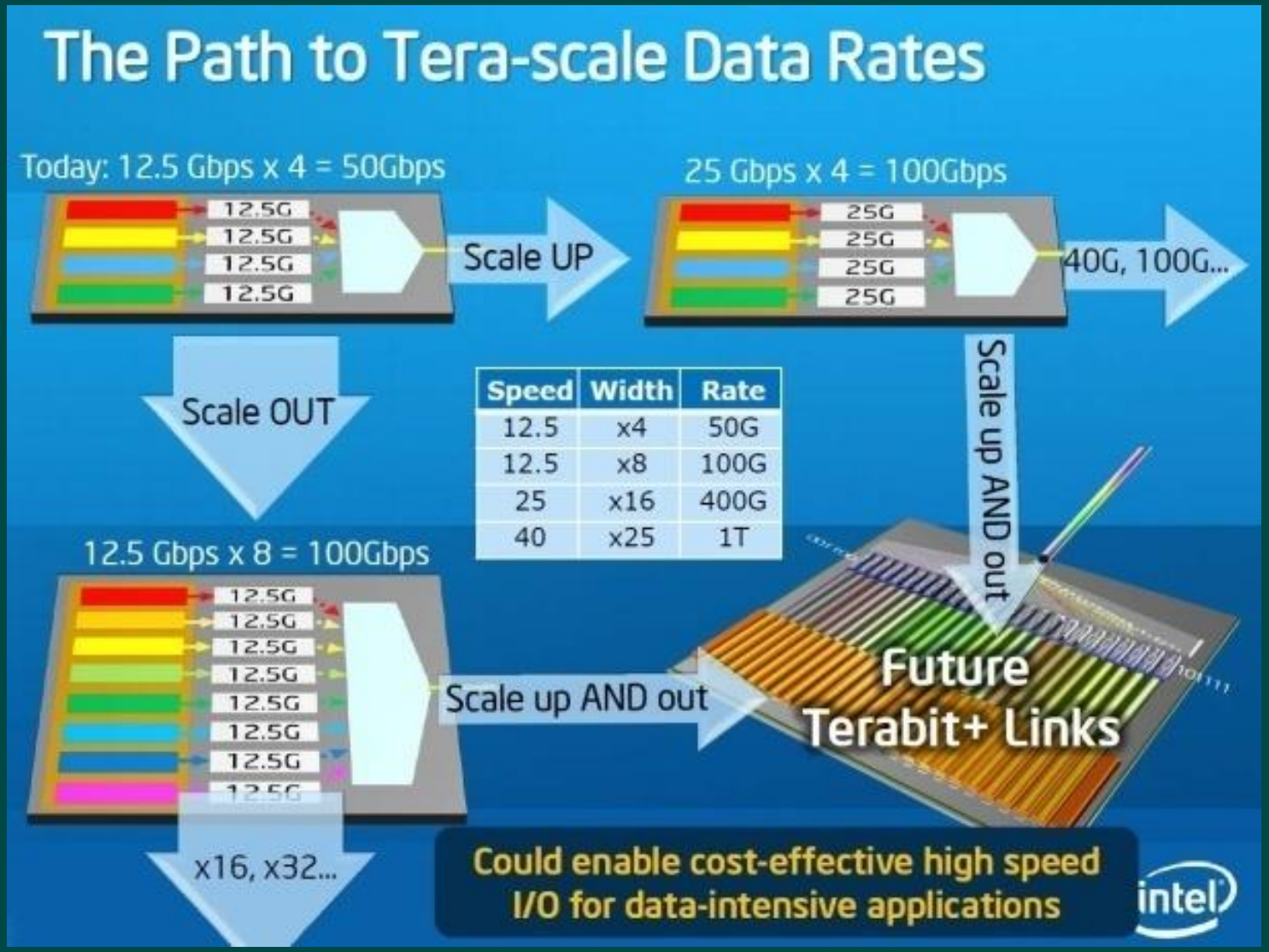

"the equivalent of an entire HD movie being transmitted every second."

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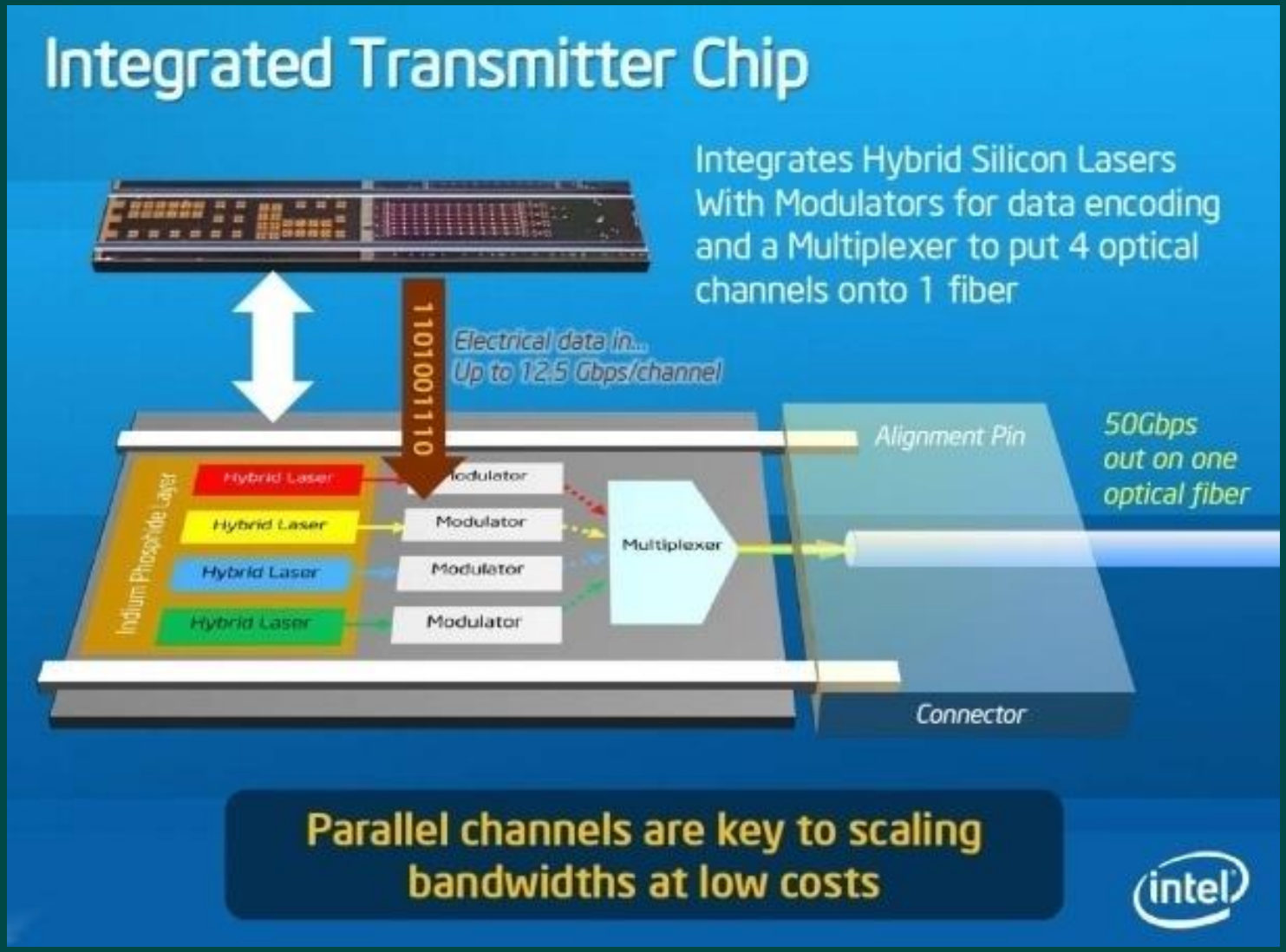

The 9,300 square metre data centre near Frankfurt

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- European data centres consumed 56TWh of electricity in 2007 and in the UK they are responsible for almost three per cent of electricity use.

Datacentres – Bandwidth Management for the Cloud

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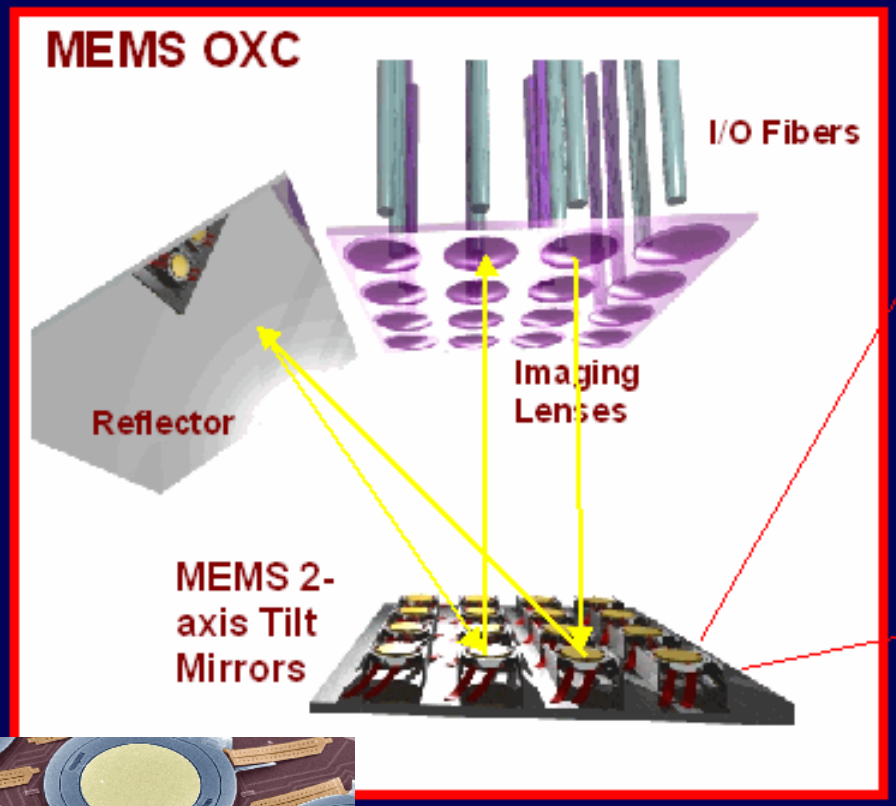
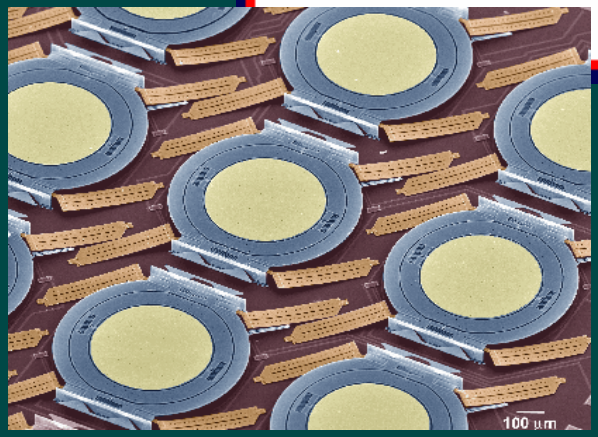
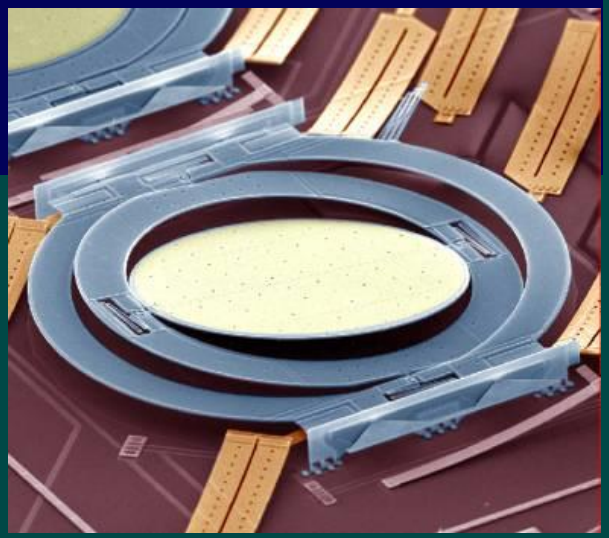
Lucent MEMS OXC



MEMS DEVICE:

- 2-axis, angular range of > ±6°
- continuous, controlled tilt
- directly scalable to 256 mirrors (1024 in the long term)
- simple technology for rapid development / prototyping
- manufacturable





Glimmerglass Intelligent Optical Switch

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System 500

32x32 - 190x190

210 gold-coated mirrors, 1 mm diameter

Glimmerglass Intelligent Optical Switch

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- Transparent, Non-Blocking Fiber Connections

  Connects input fibers to output fibers (in x out)
- Single mode fiber, wideband (1270 nm - 1630 nm)
- Connects fibers transparently, using MEMS micro mirrors
- All traffic data rates Up to OC-768, 10GE and DWDM
- Transparently accepts all signal formats: SONET/SDH, Ethernet, digital, or analog
- Sizes from 24x24 to 190x190 fibers

Undersea fiber-optic cables

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Government Signal Monitoring

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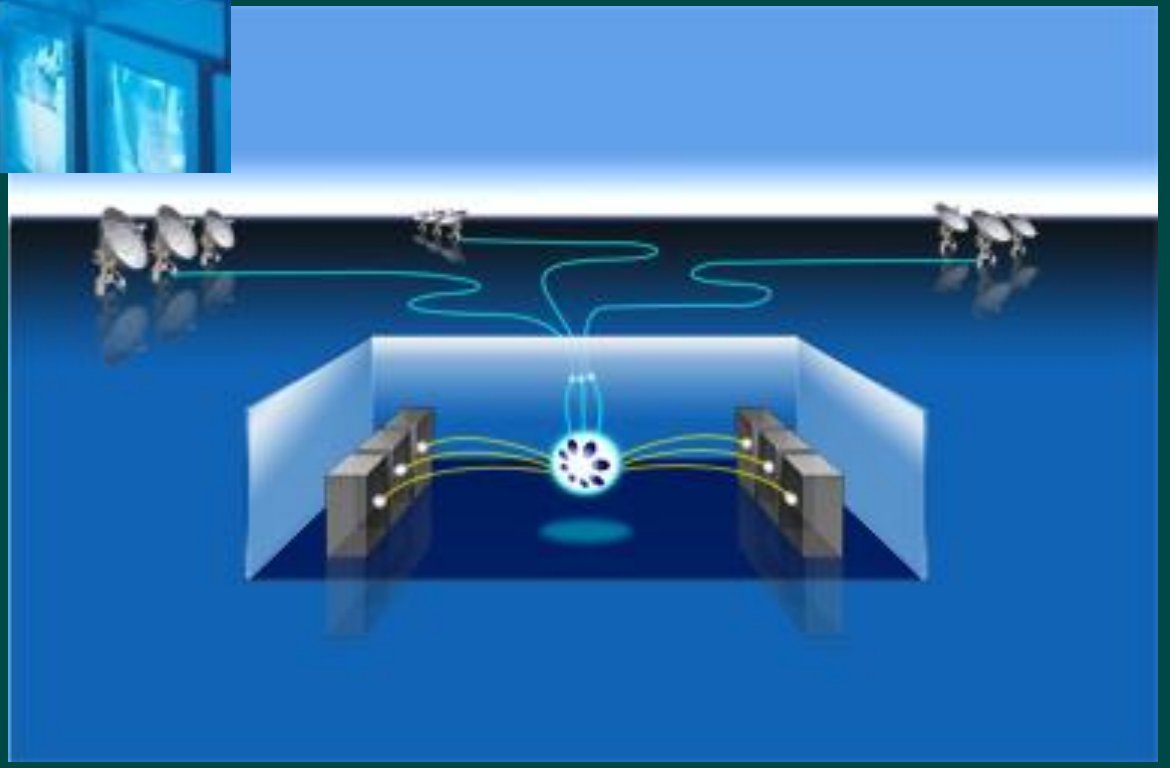

Government Signal Monitoring

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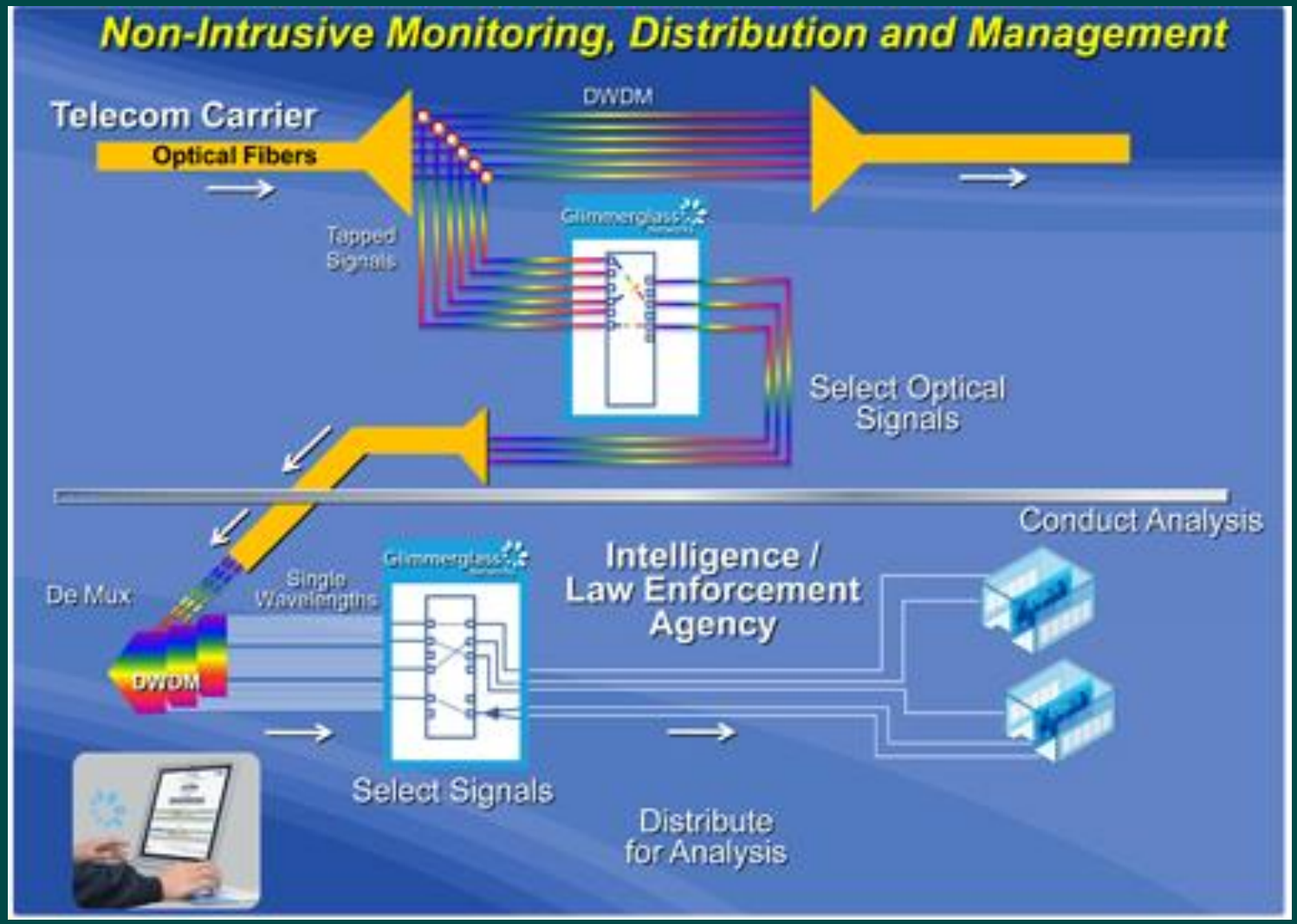

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GCHQ

GCHQ's headquarters are in Cheltenham, Gloucestershire. There are two much smaller sites in Cornwall and Yorkshire but most of the 5500 staff work at the impressive state of the art building at Benhall in Cheltenham.

Information Integration Systems relating to Individuals

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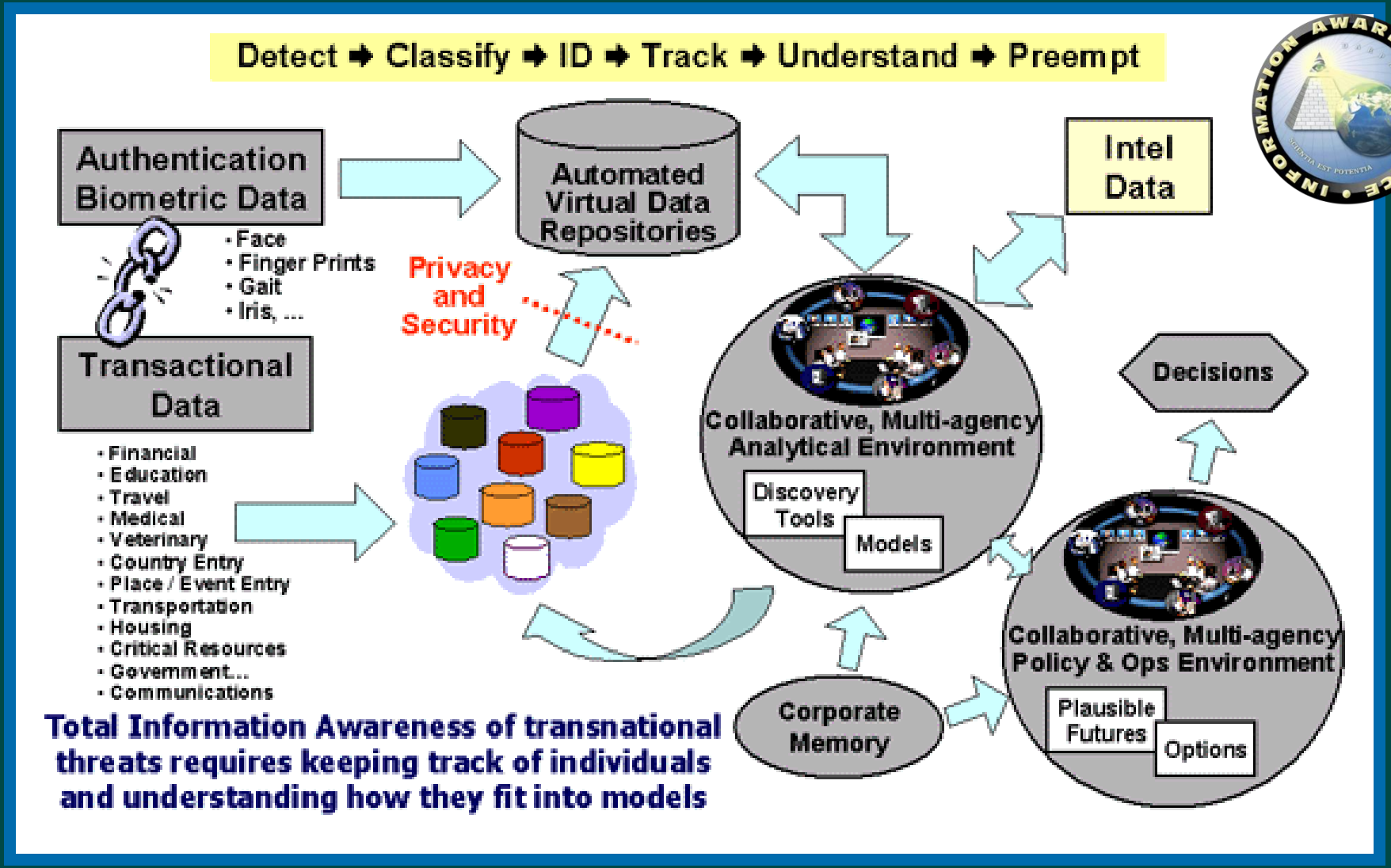
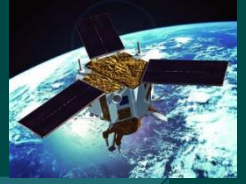




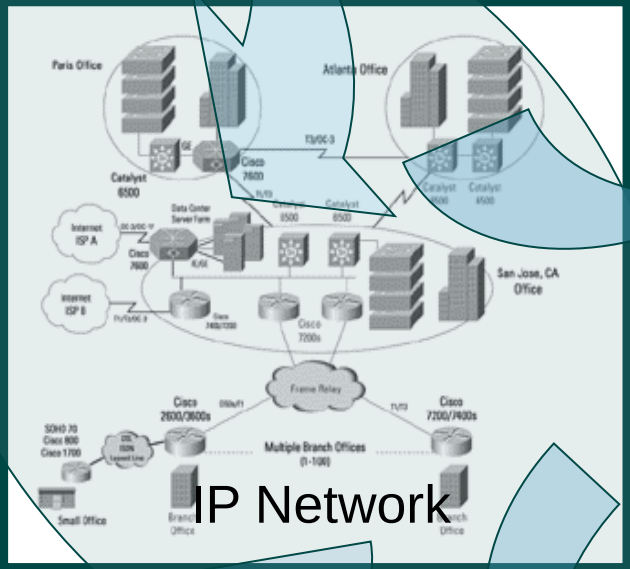



Urban Surveillance

Control Room

Alerts & Meta Data

Smart IP Cameras
mapped into 3D space



IP Network

Data & Meta-
Data Storage

Responders

A Russian Topol-12M mobile nuclear missile.

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A nuclear device detonated 500 miles above the earth could produce a crippling electro-magnetic pulse,

Conclusion

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- Bandwidth management and availability is going to improve greatly
- The Cloud will become increasingly important for security
- What can the UK manage alone?
- Important to develop and contribute to NATO

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